# Chapter 18
# A Centroid-GPS Model to Improving Positioning Accuracy for a Sensitive Location-Based System

**Md. Rashedul Islam and Jong-Myon Kim**

**Abstract** This paper proposes a centroid global positioning system (GPS) model to improve the positioning accuracy of low-cost GPS receivers of a sensitive location-based system. The proposed model estimates the precise movement position by a centroid sum of the individual improved positions of three GPS receivers. Each GPS receiver's position is improved by using a direction and velocity averaging technique based on combining the vehicle movement direction, velocity averaging, and distance between the waypoints of each GPS receiver using coordinate data (latitude, longitude, time, and velocity). Finally, the precise position is estimated by calculating a triangular centroid sum with distance threshold of the improved positions of three GPS receivers. In order to evaluate the performance of the proposed approach, we used three GARMIN GPS 19x HVS receivers attached to a car and plotted the processed data in Google map. The proposed approach resulted in an improved accuracy of about 2–12 m compared to the original GPS receivers. In addition, we compared the proposed approach to two other state-of-the-art methods. The experimental results show that the proposed approach outperforms the conventional methods in terms of positioning accuracy.

**Keywords** GPS accuracy · Long-term averaging · Direction averaging · Location-based system

## 18.1 Introduction

Location-based services (LBSs) have been an innovative information technology to identify the location or geographical position of users [1]. Several location-based systems have been introduced such as GPS, geographical information system (GIS),

---

Md.R. Islam · J.-M. Kim (✉)
Department of Electrical, Electronics, and Computer Engineering,
University of Ulsan, Ulsan, South Korea
e-mail: jongmyon.kim@gmail.com

Md.R. Islam
e-mail: rashed.cse@gmail.com

J.J. (Jong Hyuk) Park et al. (eds.), *Ubiquitous Computing Application and Wireless Sensor*, Lecture Notes in Electrical Engineering 331,
DOI 10.1007/978-94-017-9618-7_18

Wi-Fi fingerprinting, wireless sensor network (WSN), wireless local area network (WLAN), Bluetooth, and sensors for identifying indoor and outdoor location [2–4]. Among these techniques, GPS has been widely used for a wide range of location-based services due to its cost effectiveness and energy consumption [5–8].

GPS was developed in early 1960 [9], and it has been used to measure any desired position on the earth. Currently, GPS is a popular general-purpose positioning system [10, 11] that consists of three major segments: a space segment, a control segment, and a user segment [12]. The space segment is composed of the orbiting GPS satellites over 20,000 km from the earth. The control segment monitors the operation and position of GPS from a ground station. The user segment calculates the position of GPS through the signal from satellites.

Although GPS is the most popular positioning system in the field of LBS, positioning accuracy improvement of GPS is a challenging issue. Several techniques have been developed to enhance the accuracy of GPS positioning. The conventional researches are categorized into three groups [5]. Firstly, expensive devices and technologies including the wide area augmentation system (WAAS), differential GPS (DGPS), and assisted GPS (AGPS) have been developed to enhance positioning accuracy by from 3 to 15 m. However, these technologies require an expensive infrastructure. The second group uses an additional peripheral module for a GPS receiver to improve the positioning accuracy. In the third group, several researchers have developed software methods to improve the accuracy of GPS positioning [9, 11]. Refan et al. proposed auto regressive moving average (ARMA) interpolation methods to improve the accuracy of a low-cost GPS positioning and showed satisfactory performance [9]. Islam et al. [11] proposed an effective direction averaging method to improve the positioning accuracy of a low-cost standard GPS by estimating direction angle, velocity, and distance between two waypoints.

To improve the accuracy of a low-cost GPS using a sensitive location-based system, we propose a new centroid-GPS model. The proposed model precisely estimates the position as a centroid sum of the improved positions of three GPS receivers based on the vehicle movement direction, velocity averaging, and distance between waypoints. The experimental results demonstrate that the proposed model results in an improvement of about 2–12 m in several different experiments.

The rest of this paper is organized as follows. Section 18.2 describes the proposed model with related terminologies, and Sect. 18.3 presents the experimental results. Finally, Sect. 18.4 concludes the paper.

## 18.2 Proposed Approach

This paper focuses on improving the positioning accuracy of a location-based system using low-cost standard GPS receivers. This proposed approach consists of the following main functional blocks to improve the positional accuracy of GPS: (i) improvement of the individual GPS positioning accuracy using an effective direction averaging technique based on combining the movement directions and averaging speed and distances of the waypoints of past and current states of each individual GPS receiver [11] and (ii) estimating the vehicle's position using a triangular centroid sum of the improved GPS positions of the three GPS receivers. To enhance the performance of the proposed model, this study also utilized a precise reference point and invalid data check.

Three GPS receivers were placed at three corners of a vehicle to form a triangle with the centroid of the triangle located at the approximate center of the vehicle. Figure 18.1 represents the physical layout of this model, where $D_1$, $D_2$, and $D_3$ are the actual (initial) distances of the 1st–2nd, 2nd–3rd, and 3rd–1st GPS receiver, respectively.

Figure 18.2 represents a basic flow diagram of the proposed approach. In the proposed approach, the direction and velocity averaging module of each receiver

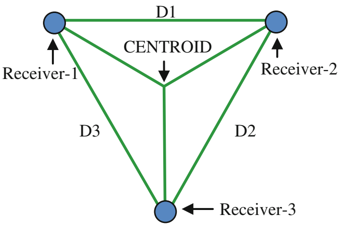
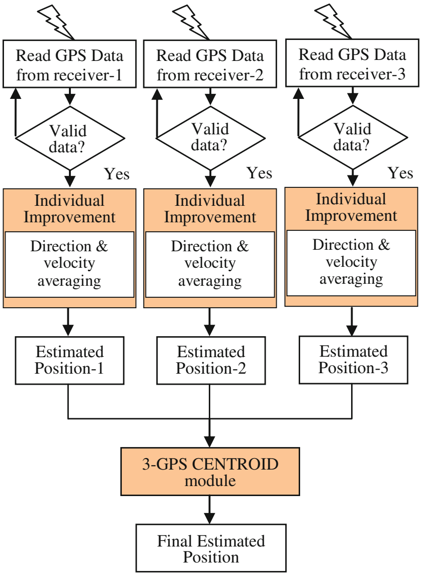


**Fig. 18.1** Physical layout of the GPS receiver position in the proposed model

**Fig. 18.2** Basic flow diagram of the proposed method



receives valid data, processes the data, and estimates the improved position for each individual receiver. Finally, the proposed approach calculates the centroid sums of the improved positions of the three GPS receivers. In following sections, we describe the details of the different functional blocks.

### 18.2.1 Accurate Calculation of the Reference Point

To estimate a precise position using the proposed method during navigation, an accurate reference point is needed. This paper utilizes a long-term averaging technique [11] to effectively calculate a reference point by using the Eq. (18.1):

$$AVG_x = \frac{1}{N}\sum_{i=1}^{N} x_i \quad \text{and} \quad AVG_y = \frac{1}{N}\sum_{i=1}^{N} y_i, \tag{18.1}$$

where $x$ is latitude, $y$ is longitude and $N$ is the number of timestamps.

### 18.2.2 Invalid Data Check

Table 18.1 shows an example of the NMEA (National Marine Electronics Association) sentence information of GPS [13]. A GPS receiver sometimes provides an invalid sentence that contains null latitude, longitude, and altitude data or invalid fixed quality or a deficient number of required satellites, which makes invalid waypoints. This step filters those error data by checking the valid data flag, the number of connected satellites, latitude, and longitude values.

**Table 18.1** Example of NMEA (national marine electronics association) sentence information of GPS [13]

$GPGGA,123519,4807.038,N,01131.000,E,1,08,0.9,545.4,M,46.9,M,,*47

Where:

| | |
|---|---|
| GGA | Global Positioning System Fixed Data |
| 123519 | Fix taken at 12:35:19 UTC |
| 4807.038,N | Latitude 48 deg 07.038' N |
| 01131.000,E | Longitude 11 deg 31.000' E |
| 1 | Fix quality: 0 = invalid, 1 = GPS fix (SPS), 2 = DGPS fix, 3 = PPS fix ... |
| 08 | Number of satellites being tracked |
| 0.9 | Horizontal dilution of position |
| 545.4,M | Altitude, Meters, above mean sea level |
| 46.9,M | Height of geoid (mean sea level) above WGS84 ellipsoid |
| (empty field) | time in seconds since last DGPS update |
| (empty field) | DGPS station ID number |
| *47 | the checksum data, always begins with * |

### 18.2.3 Position Improvement of Each Individual GPS

Before calculating a centroid sum of three GPS receivers, the proposed approach improves the positioning accuracy of each individual GPS by using the direction and velocity averaging technique [11]. The direction and velocity averaging technique enhances the positioning data by estimating direction angle, velocity, and distance between two waypoints, as shown in Fig. 18.3.

New coordinate values are estimated by Eqs. (18.2) and (18.3) [11]:

$$X'_{n+1} = X'_n + D \times \cos(\tan^{-1}\frac{y_{n+1} - y_{n-1}}{x_{n+1} - x_{n-1}}) \tag{18.2}$$

$$Y'_{n+1} = Y'_n + D \times \sin(\tan^{-1}\frac{y_{n+1} - y_{n-1}}{x_{n+1} - x_{n-1}}) \tag{18.3}$$

where the distance is calculated by $D = \sqrt{(x_{n+1} - x_n)^2 + (y_{n+1} - y_n)^2} \times \frac{V_n}{V_{n-1}}$. $X'$ and $Y'$ are the new enhanced coordinate values.

### 18.2.4 Distance Threshold and Centroid Calculation of Three GPS Receivers

The final step in the proposed approach utilizes the previously estimated positions of the three GPS receivers and then estimates a more precious position by calculating the triangular centroid of the data. Figure 18.4 shows a detailed flow diagram of the centroid calculation of the 3 GPS receivers.

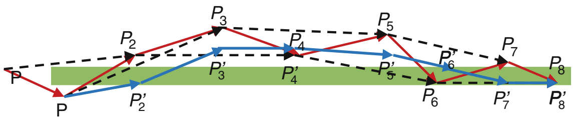
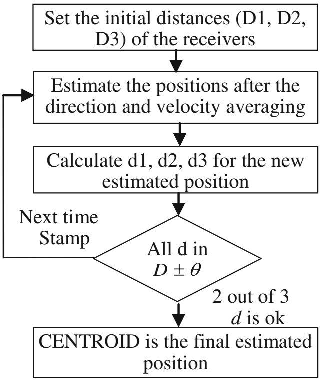


**Fig. 18.3** Direction and velocity averaging process [11]

**Fig. 18.4** Flow diagram of the centroid calculation of the 3 GPS receivers



During the initial setup, the three GPS receivers are fixed at the known distances, $D_1$, $D_2$, and $D_3$. This process receives three estimated position values and re-calculates the distances ($d_1$, $d_2$, and $d_3$) between the three new estimated points. The new distances ($d_1$, $d_2$, and $d_3$) are compared with the initially fixed distances with an error tolerance threshold ($+\theta/-\theta$). If at least 2 out of the 3 distances meet the condition, this step calculates the centroid of the three estimated points. The calculated position value is the final estimated position using the proposed model.

## 18.3 Experimental Results

In the experiment, we used three GARMIN GPS 19x HVS receivers for data collection. We attached the three receivers on a car, as shown in Fig. 18.5. The 1st and 2nd GPS receivers were attached at the left and right sides on the front of the car and the 3rd one was placed in the middle of the back of the vehicle, making a triangle configuration. Inside the car, we set up the developed simulation software on a laptop as a data processing terminal and plotted the data in Google maps.

A serial-to-USB convertor was used for the connection between the GPS receivers and the data processing terminal (laptop). Table 18.2 describes the specifications of the receivers.

We collected the GPS data while driving a car and performed several simulations at different locations. In the experiment, we ignored invalid data such as null values of latitude, longitude, time, and velocity. Figure 18.6 shows the results of the proposed approach.

**Fig. 18.5** Experimental setup for an autonomous vehicle design

**Table 18.2** The specifications of the receivers

| Type | Updating rate | Accuracy | Provided data |
|---|---|---|---|
| Standard GPS receiver | 1, 5, 10 records per second (we used 1 for steady data) | Less than 15 meters with 95 % typical | Pseudo range, integrated carrier phase, Doppler shift, satellite ephemeris, and processed data |

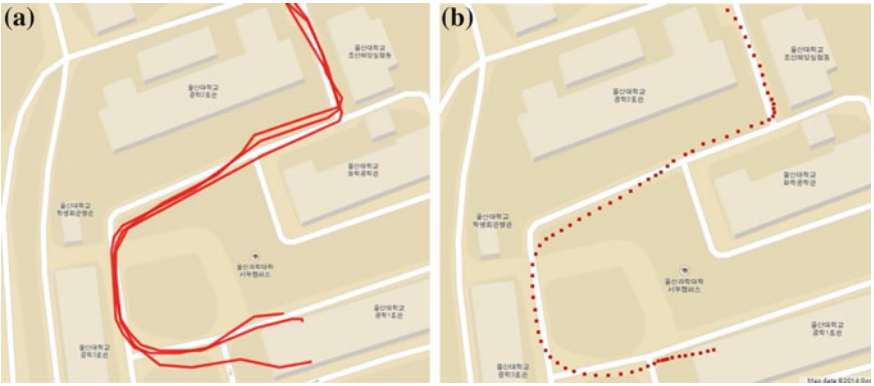


**Fig. 18.6** Experimental results: **a** real data of the three GPS receivers and **b** processed data obtained using the proposed approach

Figure 18.7 and Table 18.3 demonstrate the improvement of the latitude and longitude values with the new estimated waypoints over the original GPS receiver's data, where the red dashed line represents the improvement of GPS receiver 1, the blue stared line is for receiver 2, and the black solid line corresponds to receiver 3.

The proposed approach resulted in an accuracy improvement of about 2–12 m during driving. In addition, we compared the results obtained from the proposed approach with two conventional methods, ARMA interpolation [9] and direction averaging [11]. Table 18.4 shows the average improvement (in meters) obtained using the proposed approach and other state-of-art models. The ARMA interpolation has two coefficient parameters which impact the accuracy of the new estimated points. On the other hand, the direction averaging method estimates the new position based on the last 2 steps of one GPS receiver. In this case, it cannot improve the positional data due to significant errors. Overall, the proposed method outperforms the other methods in terms of positioning accuracy.

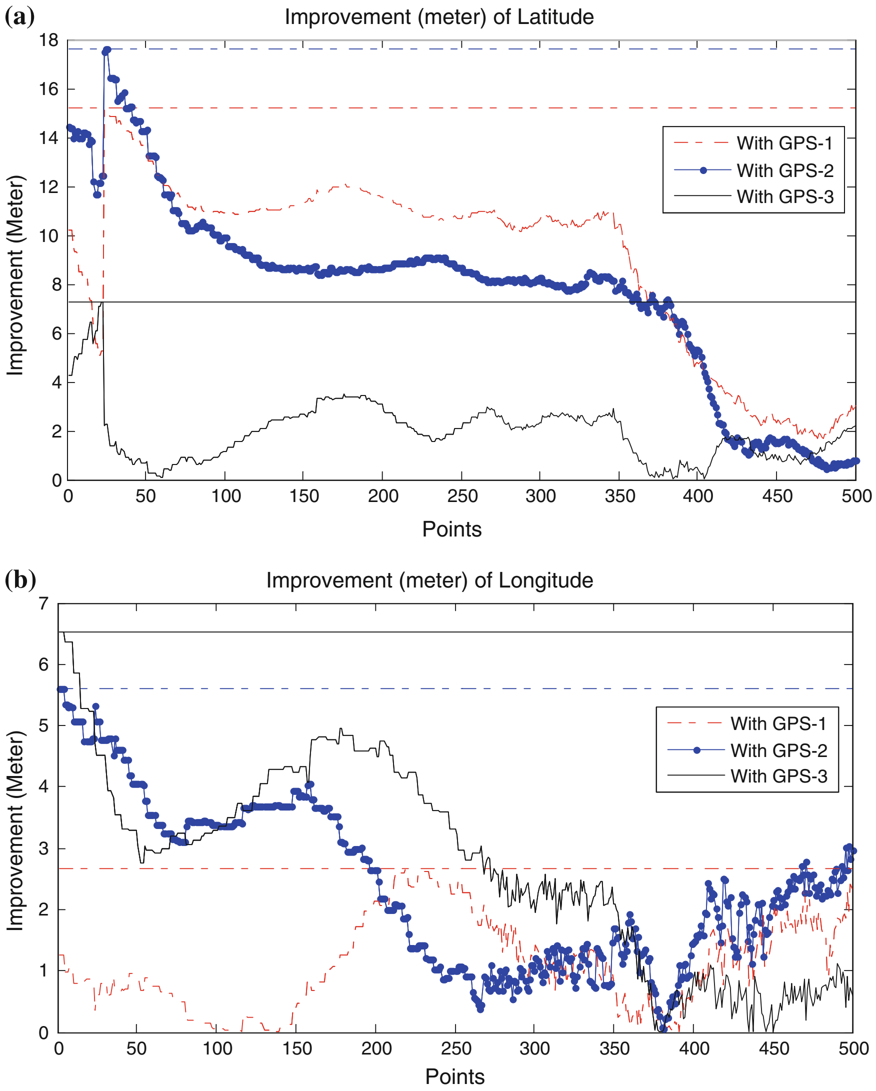


**Fig. 18.7** Improvements of the coordinate position values using the proposed model for the 1st, 2nd, and 3rd GPS receivers: **a** latitude and **b** longitude

**Table 18.3** Improvement of the maximum and average coordinate values (in meters) utilizing the three receiver's data

| | With GPS-1 | | With GPS-2 | | With GPS-3 | |
|---|---|---|---|---|---|---|
| | MAX | AVG | MAX | AVG | MAX | AVG |
| Latitude | 15.203 | 11.731 | 17.589 | 8.672 | 7.271 | 2.562 |
| Longitude | 2.665 | 1.825 | 5.607 | 2.855 | 6.536 | 3.152 |

**Table 18.4** Improvement of the average coordinate values (in meters) of the proposed model and other state-of-art methods

| Experiment number | Proposed approach | | ARMA interpolation | | Direction averaging | |
|---|---|---|---|---|---|---|
| | Latitude | Longitude | Latitude | Longitude | Latitude | Longitude |
| 1 | 8.439 | 9.312 | 5.167 | 6.212 | 7.535 | 6.813 |
| 2 | 6.977 | 5.747 | 3.236 | 3.571 | 4.512 | 3.563 |
| 3 | 11.731 | 1.825 | 7.718 | 4.544 | 8.955 | 4.452 |
| 4 | 9.856 | 8.594 | 2.497 | 4.981 | 6.253 | 6.125 |
| 5 | 6.945 | 4.221 | 1.416 | 4.204 | 4.265 | 5.565 |

## 18.4 Conclusion

This paper proposed a centroid-GPS approach to improve the positioning accuracy using three low-cost GPS receivers. The proposed approach estimates positions by employing the direction angle, speed, and distance of three GPS receivers with the help of an accurate reference point by using long-term averaging and an invalid data check. In the experiment, we used three GARMIN GPS 19x HVS receivers to evaluate the positioning accuracy of the proposed approach and two other conventional methods. The experimental results showed that the proposed approach improves the coordinate position more efficiently and outperforms other conventional methods in terms of positioning accuracy by significantly reducing data fluctuation.

**Acknowledgments** This work was supported by 2014 Funds of LG Yonam Foundation.

## References

1. Mahmood FM, Salam ZABA (2013) A conceptual framework for personalized location-based Services (LBS) tourism mobile application leveraging semantic web to enhance tourism experience. In: IEEE 3rd international advance computing conference (IACC 2013), Ghaziabad, India, pp 287–291
2. Luo Y, Hoeber O, Chen Y (2013) Enhancing Wi-Fi fingerprinting for indoor positioning using human-centric collaborative feedback. Hum-Centric Comp Info Sci 3(2):1–23
3. Lin P, Li Q, Fan Q, Gao X, Hu S (2014) A real-time location-based services system using WiFi fingerprinting algorithm for safety risk assessment of workers in tunnels. Math Prob Eng 2014:1–10
4. Brković M, Simić M (2014) Multidimensional optimization of signal space distance parameters in WLAN positioning. Sci World J 2014:1–6
5. Huang J, Tsai C (2008) Improve GPS positioning accuracy with context awareness. In: First IEEE international conference on Ubi-Media computing, Lanzhou, China, pp 94–99
6. Hong S, Chang J (2013) A new k-NN query processing algorithm based on multicasting-based cell expansion in location-based services. J Convergence 4(4):1–6

7. Bisio I, Lavagetto F, Marchese M, Sciarrone A (2013) GPS/HPS-and Wi-Fi fingerprint-based location recognition for check-in applications over smartphones in cloud-based LBSs. IEEE Trans Multimedia 15(4):858–869
8. Zarazaga FJ, Álvarez PJ, Guillo J, López R, Valiño J, Muro-Medrano PR (2000) Use Cases of vehicle location systems based on distributed real-time GPS data. In: TeleGeo'2000: second international workshop on telegeoprocessing, Zaragoza, Spain, pp 53–61
9. Refan MH, Palangi H (2012) Positioning error reduction of a low-cost GPS receiver for kinematical applications. Am J Sci Eng 37:2221–2230
10. Garcia J, Zhou C (2010) Improving GPS precision and processing time using parallel and reduced-length wiener filters. J Telecom 2(2):91–98
11. Islam R, Kim J (2014) An effective approach to improving low-cost GPS positioning accuracy in real-time navigation. Sci World J 2014:1–8
12. Pike J (2009) GPS III operational control segment (OCX). http://Globalsecurity.org. Accessed 8 Dec 2009
13. GPS—NMEA sentence information. http://aprs.gids.nl/nmea/. Accessed 20 June 2014