METHODOLOGY FOR THE POSITIONAL ACCURACY ASSESSMENT OF GNSS TRACKING DATA COLLECTED FROM NAVIGATION RECEIVERS

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ABSTRACT

Currently, the navigation receivers are very common in daily activities. It can be cited several specific devices for localization (Garmin, TomTom, among others), as well as in telecommunications devices (smartphones, tablets, etc.). This work aimed to assess the planimetric positional accuracy of the navigation receivers Garmin ETrex Vista Hcx and Smartphone Samsung Galaxy S7 Edge, applying the Equivalent Rectangle Method (ERM), considering the reference lines obtained simultaneously by the kinematic relative positioning of a pair of geodetic receiver Trimble R6 with greater accuracy. The results show that the smartphone has positional accuracy next to the Garmin and the tracking data of the two receivers can be applied in mapping activities requiring PEC-PCD class "A" for the scale 1:10,000.

***Keywords* — *Positional accuracy, GNSS navigation receiver, Garmin, Smartphone, ERM*.**

1. INTRODUCTION

The Global Navigation Satellite System (GNSS) currently has the North American GPS, Russian GLONASS, the European Galileo and the Chinese Beidou-Compass [1]. GNSS satellites orbit approximately 20,000 km from the Earth's center of gravity, transmitting positioning information and completing approximately two rounds around the Earth per day. The orbits are arranged so that at any point on the Earth's surface, the maximum number of satellites are visible, that is, above the horizon line [2].

A GNSS receiver is intended to locate at least four satellites, determine the distance to each of them and, from this information, calculate its own position (X,Y,Z) and synchronization of its clock (time) [1]. This operation is based on the mathematical solution called trilateration [3].

It should also be assumed that certain atmospheric factors and other sources of errors, such as places with large buildings, can affect the accuracy of a GPS receiver [3].

The satellites can transmit the positioning data on the frequencies L1, L2 or L5, transmitting the following pseudorandom codes (PRN): Coarse/Acquisition (C/A) and Precision code (P-code). The C/A code is modulated in carrier L1 (civil use), since the code P (military use) is modulated in all carriers L1, L2 and L5 [1] [4].

The GNSS receivers are classified according to their accuracy and purpose in geodetic receiver, which has greater precision and are suitable for topographic surveys and navigation receiver, which has less precision, since it only uses the C/A code, available for all users [5], being applied for locomotion, fleet control, reconnaissance and reambulation [2] [6].

From the point of view of the techniques used in the GNSS positioning, the navigation receivers usually perform the positioning by point (absolute), collecting the information only from the visible satellites at that moment. On the other hand, the geodetic receivers obtain more accurate results when the relative positioning is carried out, where a pair of receivers (*Base* and *Rover*) collect information from visible satellites simultaneously [2]. The mathematical model of the double difference of the observations eliminates the clock errors of the satellites and receivers and minimizes atmospheric errors in short baselines [7].

Currently, the navigation receivers are common in our daily lives. In addition to being found in several navigation devices (Garmin, TomTom, among others), they are also present in telecommunications devices like smartphones and tablets.

In the navigation receivers, the coordinates (latitude, longitude and altitude) of a position can be determined in real time and shared through various formats [8]. When the receiver is used to track a path and share them through a file, so each route is stored in a *Track*, i.e., lines consisting of *Track Points* [9].

The most commonly used communication protocol between the GNSS receiver and another device is the NMEA 183 standardized by the National Marine Electronics Association (NMEA). The messages are transmitted by the tracker in blocks (frames), made up of several characters in the ASCII standard [1]. The most commonly used XML standard file format for sharing track tracking data is the GPS Exchange Format (GPX) [10].

In addition to using GNSS, positioning with telecommunication devices (smartphones) can also be determined by the multilateration of radio signals of cell towers of a network, when at least the roaming signal of the communication towers (antennas) of the vicinity is received, taking also into consideration the strength of the signal of each antenna. This process is called positioning in Global System for Mobile Communications (GSM) [4]. The combination of GNSS positioning with GSM can ensure greater robustness in determining the coordinates of the tracked positions.

In this context, the objective of this work is to study and evaluate the planimetric positional accuracy for the tracking data of a trajectory (*Track*) collected simultaneously by a smartphone and a Garmin GPS navigation receiver, with reference to the data collected by a GNSS geodetic receiver of greater accuracy by the Equivalent Rectangle Method (ERM).

2. MATERIALS AND METHODS

The study area corresponds to a section of Joaquim Nabuco Avenue in the city of Olinda, Pernambuco - Brazil (Figure 1). The Track of the trajectory was collected simultaneously by a geodetic receiver and two types of navigation receiver (Figure 2). The first is a Garmin eTrex Vista Hcx whose positioning is based only on GPS and the second is a Smartphone Samsung Galaxy S7 whose positioning is based on GPS, GLONASS and GSM.

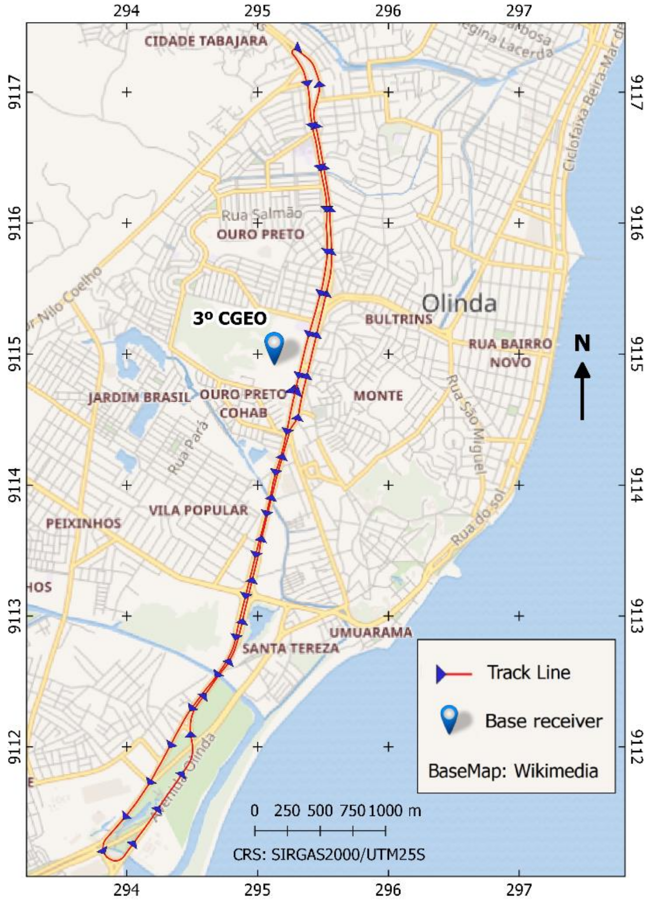

Figure 1: Study Area.

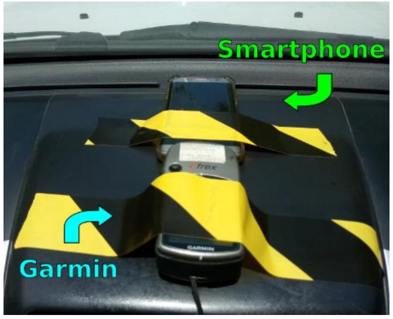

Figure 2: Navigation receivers in the center of the vehicle panel.

The Reference Lines (RL) were collected using a pair of Trimble R6 geodetic receivers, where the base receiver tracked a known coordinate point and the rover was placed on the centerline of a vehicle (Figure 3). The GNSS data were processed by the kinematic relative post-processed method with 8 mm of horizontal precision, using the software Topcon Tools.

Figure 3: Geodetic Receiver (Base and Rover).

All receivers were configured to track simultaneously at 1-second intervals, considering a minimum distance of 1 meter between each *track point*. The vehicle's average velocity was approximately 40 Km/h.

Each Test Line (TL) of the paths tracked by the Smartphone and Garmin were evaluated in relation to the respective Reference Lines (RL) tracked by the geodetic receiver. The method used for calculating the average discrepancies was the Equivalent Rectangle Method (ERM), which models two homologous lines by a rectangle with the same area and perimeter (Figure 4) [11].

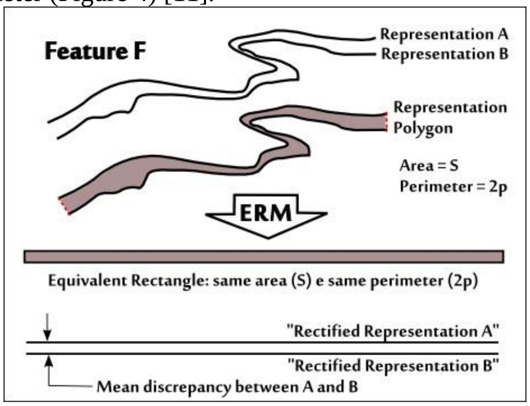

Figure 4: Equivalent Rectangle Method (ERM) [11].

The lines tracked by the Garmin and Smartphone receivers (TL in each case) were submitted to the geoprocesses explained in the flowchart of Figure 5, in order to ensure that all TLs that intercept some RL are broken at the point of intersection and vice versa. In addition to ensuring its metric unit, in this case when projected to the SIRGAS2000/UTM 25S Coordinate Reference System (CRS).

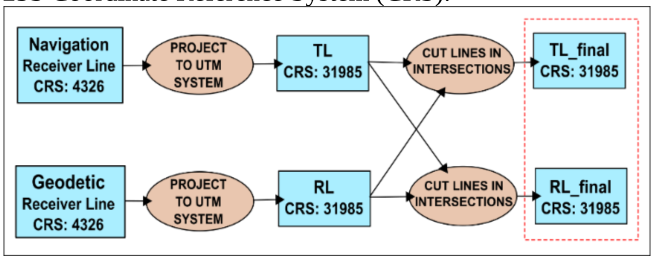

Figure 5: Geoprocessing workflow for preparing the TL and RL.

It was adopted the positional quality classification criterion proposed by [11] which makes an analogy to the PEC-PCD for homologous points, by weighing the value of the discrepancies of the line pairs based on their lengths.
Thus, it was used the Weighed Root Mean Square Error ($RMSE_W$)[11], which is given by equation 1, where *dm* is the mean discrepancy and *l* is the length of each TL.

$$RMSE_W = \sqrt{\frac{\sum_{i=1}^{N} dm_i^2 . l_i}{\sum_{i=1}^{N} l_i}} \quad (1)$$

In this work, the parameters of the Cartographic Exactness Standard for Digital Cartographic Products (PEC-PCD) for the scales 1:25,000 to 1:1,000 of the Brazilian systematic mapping (Table 1) were considered for evaluation of the planimetric positional accuracy [12].

Table 1: Mean Error (*Erro Médio* - EM) and Standard Error (*Erro-Padrão* - EP) values in meters for the classification of PEC-PCD for Vector Geospatial DataSet.

Type	PEC-PCD class	1:1,000		1:2,000		1:5,000		1:10,000		1:25,000	
		EM	EP	EM	EP	EM	EP	EM	EP	EM	EP
Planimetric measurements	A	0,28	0,17	0,56	0,34	1,40	0,85	2,80	1,70	7,00	4,25
	B	0,50	0,30	1,00	0,60	2,50	1,50	5,00	3,00	12,50	7,50
	C	0,80	0,50	1,60	1,00	4,00	2,50	8,00	5,00	20,00	12,50
	D	1,00	0,60	2,00	1,20	5,00	3,00	10,00	6,00	25,00	15,00

Source: [12].

3. RESULTS

The tracking began in 2018-10-03T13:49:02 and finished in 2018-10-03T14:08:30, with the total of 19 minutes and 28 seconds. The distance traveled was approximately 12,646 meters.
A total of 67 pairs of homologous lines (TL and RL) were tested for the Garmin, while for the smartphone were 65 pairs. The length's sum of all homologous lines varied from 0.6 m to 4,321.3 m

Table 2 presents some statistics measurements of the positional accuracy of the set of homologous line pairs for the cases of Garmin and Smartphone.

Table 2: Statistical results in meters of planimetric positional accuracy.

Measurement	Garmin	Smartphone
Maximum discrepancy	1.633	3.048
Minimum discrepancy	0.002	0.000
$RMSE_W$	1.005	1.473

The classification of the PEC-PCD for the planimetric positional accuracy of the track lines of each navigation receivers is given in Table 3.

Table 3: PEC-PCD classification of each navigation receiver.

Receiver	1:1,000	1:2,000	1:5,000	1:10,000	1:25,000
Garmin	-	D	B	A	A
Smartphone	-	-	B	A	A

4. DISCUSSION

It is observed that, according to the results obtained (Tables 2 and 3), both the Garmin and Smartphone Tracks have similar planimetric positional accuracy, being the accuracy of the Garmin slightly better.
In terms of application for the Brazilian systematic mapping, both devices can be used to generate cartographic products in the scale 1: 5,000 and smaller. Garmin obtained PEC-PCD class "D" in the scale 1:2,000, on the other hand, the Smartphone did not reach the minimum standard for PEC-PCD classification.
A possible reason for the difference in the results on the Smartphone can be attributed to the complementary technologies to GNSS positioning, such as the use of the trilateration of three or more communication towers, also known as base stations (Figure 6), creating a hybrid positioning system together with GNSS [4].

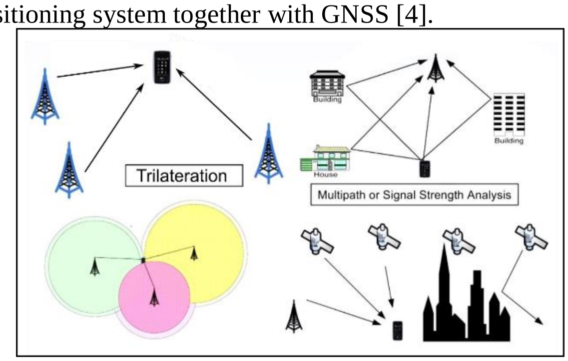

Figure 6: Positioning enhancement for Mobiles (smartphones) [4].

Another reason for the difference of results can be attributed to the number of captured signals from satellites. The Smartphone also tracks the GLONASS constellation signal in addition to the GPS constellation. The increasing number of observations is intended to improve the results, but may also interfere undesirably, depending on signal quality.

5. CONCLUSIONS

The Garmin receivers have already been used by the Geographic Service Bureau (*Diretoria de Serviço Geográfico* - DSG) in the reambulation activities in the Bahia state mapping project [6] for navigation with the QGIS and for collecting coordinates of points of interest.

With the obtained results in this work, it was possible to prove that the planimetric positional accuracy of the smartphone is comparable to that of the Garmin navigation receiver, both are classified as PEC-PCD class "A" for the 1: 10,000 scale with RMSEw of 1.0 m and 1.5 m for the Garmin and Smartphone, respectively.

In addition, smartphones have the advantage of having high connectivity for data transfer via USB cable, Bluetooth, wi-fi, etc. [8]. Furthermore, the modern smartphones are embedded with accelerometer, gyroscope and gravity virtual sensor, providing the enhancement of positioning. These sensors also allow the indoor positioning [13], in particular where the GNSS is not available, for example, in an underground parking or a tunnel.

In this way, smartphones are a low-cost alternative not only for reambulation but also for other applications such as updating road maps, aiding photogrammetric flights, engineering reconnaissance, fleet and equipment's monitoring and control [9].

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