Positional Accuracy Assessment of the VGI Data from OpenStreetMap

Case Study: Federal University of Bahia Campus in Brazil

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Abstract: Geographic information is a crucial part of the daily lives of billions of people and is constantly used in decision-making processes for geospatial problems. With the increasing dissemination of information technology in society there has been a great gain in terms of the quantity and quality of spatial information available to internet users. This paper evaluates the positional quality of data from the Open Street Map platform (OSM) and uses data from a cartographic accuracy standard from the same region for this evaluation. The methodology section presents the methodology proposed by the Brazilian PEC-PCD which divides cartographic products into accuracy classes. For the data evaluated, the vectors from the OSM obtained better accuracy in the 1:30,000 scale.

1 INTRODUCTION

Rapid computational technological advances have made it so that users of cartographic products do not only view these products, but have wanted to become part of the production of the information contained in them and of their dissemination and democratization through the internet. This level of involvement became possible beginning with the establishment of the concept of Web 2.0, created by O'Reilly (2007). According to Cormode and Krishnamurthy (2008), Web 2.0 is defined as a cybernetic phenomenon where users become fundamental players in the generation and management of certain information, rather than simply consumers of said information.

In this context, the concept of Volunteered Geographic Information (VGI), which, according to Bravo (2014), is a system with the features described where the maps that were once developed by users with a certain amount of technical training in cartography begin instead to be created by individuals who have access to a computer and internet. Thus, VGI systems allow the users of this tool to collect and publish geographic information and even validate the information posted by other users (Goodchild, 2007).

Currently, VGI data is stored and accessed on online platforms that allow users to perform such operations. Despite the efficiency with which these products are available and the constant updating of the information with which individuals make changes to the geographical setting, VGI data sources do not constitute model cartography, since quality parameters for the maps presented are still provided. With the premise that the data is current and understanding this to be one of the major problems with high quality maps, this work consists in evaluating positional accuracy, one of the quality parameters of the study area.

2 THEORETICAL REFERENCES

2.1 Systems of Volunteered Geographic Information

The development of computational technology in the most diverse areas of the science has brought new perspectives to cartography regarding the production and handling of spatial information since these processes can now occur through any individual who has access to a computer and the internet (Ganapati et al, 2011). Thus, according to Goodchild (2007),

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there are systems that enable everyday users, who are not skilled in spatial data production and manipulation techniques, to construct and elaborate products that represent the geographic space according to their perceptions. The dissemination of VGI (Volunteered Geographic Information) systems has modified perceptions of cartography, making it so that certain information about the environment is attributed through individuals' perceptions. In addition, VGI data has been handled, due to the constant updating of the products generated in its platforms, so that it can feasibly be used in applications for model cartography that feeds official cartographic basemaps.

Goodchild (2007) also states that activities involving VGI platforms came from the combination of the popularization of online maps and the internet itself, the emergence of Web 2.0, and the growth of crowdsourcing platforms. Linked to this combination, the technological advances in communication tools that allow mobile connection with internet data has favored the sharing of data in real time and the consequent localization and obtaining of information in an automated way through receivers and GPS devices on tablets and smartphones.

2.1.1 OpenStreetMap

The goal of the OSM project is to create a free and editable world map (Ramm et al. 2011). Within the project volunteers, amateurs and professionals from different social worlds act as sensors (Flanagin and Metzger 2008) and collect geographic data. This bottom up process stands in contrast with the traditional centralized procedure of collecting geographic data (Goodchild 2007). The motivation for contributing to OSM varies heavily: it ranges from self-expression over manifestation and representation of people's online identity to a simple fun factor. Meaningful extracurricular activities, interesting technologies and a fascinating general project development are further motivational reasons (Budhathoki 2010). In general, data for OSM can be derived from multiple sources and edited and imported by means of different freely available editors. The most popular editors are the Java OpenStreetMap Editor (JOSM) or the webbased JavaScript editor iD. The classic approach is the collection of spatial data with portable and GPS enabled devices. In addition, several companies such as Aerowest, Microsoft Bing (Bing 2010) or Yahoo! released, at least temporarily, their aerial images for the OSM project. The community is allowed to use these images as a base layer for tracing geographic features, such as for example buildings, forests or lakes. The contributors' local knowledge is also a valuable source of geographic Based on Barron et al (2014) the goal of the OSM project is to create a free and editable world map Ramm et al.(2011). Within the project volunteers, amateurs and professionals from different social worlds act as sensors Flanagin and Metzger (2008) and collect geographic data.

2.2 Quality Control

According to Barron (2014) quality in general plays a key role when working with all kinds of geodata, especially in data production and assessment (Veregin 1999) or exchange (Goodchild 1995). This is especially the case with OSM data, as the contributors are not faced with any restrictions during the data collection and annotation process. In the field of geo-information, the principles of the "International Organization for Standardization" (ISO) can be taken into account for quality assessment. The ISO 19113 standard describes general principles of geodata quality and ISO 19114 contains procedures for quality evaluation of digital geographic datasets. The ISO 19157 "Geographic Information: Data Quality" standard currently under development, aims to harmonize all standards related to data quality and revises the aforementioned standards. The quality of spatial data can be evaluated with the help of following elements of ISO 19113:

• "Completeness": describes how complete a dataset is. A surplus of data is referred to as "Error of Commission", a lack of data in contrast as "Error of Omission".
• "Logical Consistency": declares the accuracy of the relations manifested within a dataset. This element can be further subdivided into "intra-theme consistency" and "inter-theme consistency".
• "Positional Accuracy": defines the relative and absolute accuracy of coordinate values.
• "Temporal Accuracy": the historical evolution of the dataset.
• "Thematic Accuracy": describes the accuracy of the attributes assigned to a geometry. However, OSM data quality heavily depends on the purpose for which the data will be deploye.

2.2.1 Positional Accuracy

According to Nero (2017) the control quality process is quite well-known, having been applied to positional accuracy of spatial data as in Ariza-López et al (2001), Ariza-López (2002a), Atkinson-Gordo, Ariza-López and García-Balboa (2007) and Cintra and Nero (2015), generating mappings with different point percentages with errors in a given coordinate, above (or below) a limit established by a specific set of standards (CAS-Circular Accuracy Standard, LMAS-Linear Accuracy Standard, among others). Quality control guidelines for cartography are employed by several countries. The standards set by CONCAR (2011, 2016 - Brazilian Commission of Cartography), for example, allow up to 10% of the points to present an error greater than 0.5mm, in the scale of B class of cartographic documents.

3 METHODOLOGY

The methodology used in this article is the same as that applied in the evaluation of cartographic mapping in Brazil based on the cartographic quality standard parameters for digital products - PEC-PCD (2011). In June 2011, the Technical Specifications for the Acquisition of Geospatial Vector Data (ETADGV) were created by the National Commission of Cartography (CONCAR). This document was based on aspects of England's Ordnance Survey. The area included in the study is Bahia Federal University – UFBA. In 2009 a topographic planimetric and altimetric survey was done of the university area, obtaining as its final product a topographic plan with a scale of 1:500 and representation in the scale of 1:2000. Thus, from this cartographic basemap, this same area was obtained on the OSM online platform. After obtaining this information, it was then possible to identify equivalent features between these two cartographic products, making it possible to perform comparative analyses to evaluate the positional accuracy of OSM in the vicinity of the university

3.1 Determining the Number of Samples

The verification of accuracy with respect to the characteristics of the features located in a given cartographic product is done differently in every country. According to Nogueira Jr. (2003) this difference is due to the variations and peculiarities of each locality such as the spatial division, scale, economic situation, etc.

According to Merchant (1982), the accuracy of a map must be verified by comparing at least 20 points of the terrain coordinates to the cartographic product generated.

The sampling process depends on the type of information that is to be analyzed. In other words, when defining the samples to be used, it is necessary to ensure that they will correctly represent the attributes of the statistical population, validating their application.

Although it is extremely important to determine sample size for the purposes of cartographic analysis, most methods for geometric quality assurance do not present recommendations for sample calculation (Nogueira Jr., 2003).

The minimum size of samples to be used can be calculated from the expression (01) where it is determined by means of a finite population with estimation of the population mean (μ), maximum admissable error (ε) and confidence level $(1-\alpha)$ in which the parameters are to be defined.

$$n = \frac{Z^2\sigma^2 N}{(N-1)\varepsilon^2 + Z^2\sigma^2} \quad (1)$$

where:
n = sample size;
Z = confidence interval;
N = population size;
σ = sample standard deviation;
ε = sample relative error.

3.2 Selecting the Equivalent Features

Using the initial data, the first analyses were based on the observation of features located in the topographic plan that could be easily identified in the OSM vector files. This made it possible to extract the coordinates of these elements, allowing the necessary comparisons to be made. Figure 1 shows, respectively, the identification of a certain point in the topographic plan and its equivalent feature in the online platform of the OSM. This point corresponds to the vertex of a building of the University Restaurant (RU) located in UFBA's Ondina campus.

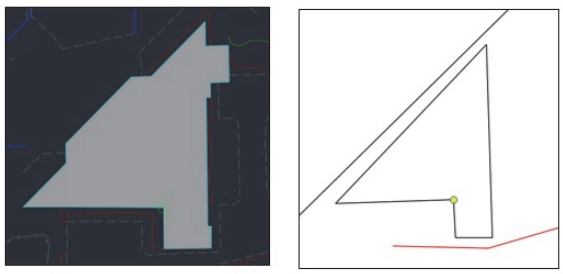

Figure 1: Homologous feature: Topographic plan and Online Platform - OSM.

3.3 Determining Positional Accuracy

According to Merchant (1982), the statistical analysis for determining planimetric positional accuracy is composed of two phases: trend analysis and precision analysis.

3.3.1 Trend Analysis

According to Nogueira Jr. (2003), in a given cartographic product the trend analysis of its elements consists of statistical analyses between the real world reference coordinates of certain features obtained by a given survey method (Xi) and the coordinates of the chart to be evaluated (Xi_c). The main purpose of this analysis is to verify the existence of trends in errors in some direction in the chart. First it is necessary to calculate the discrepancies between the coordinates as follows:

$$\Delta \mathrm{Xi} = \mathrm{Xi} - \mathrm{Xi_c} \tag{2}$$

It is worth emphasizing that the discrepancies between the coordinates and the statistical analyses must be performed in relation to the two elements that make up the pair (latitude and longitude), thus making it possible to determine the direction of the error in the chart studied. Knowing the data concerning the discrepancies between the coordinates, as well as the sample size used for the statistical analyses, the average can be calculated $(\overline{\Delta X})$ as well as the standard deviation $(S_{\Delta x})$ in order to determine the trend in the chart. In order to carry out the trend test, the following hypotheses are used:

$$\mathrm{Ho:}\ \overline{\Delta \mathrm{X}} = 0 \tag{3}$$

$$\mathrm{Hi:}\ \overline{\Delta \mathrm{X}} \neq 0 \tag{4}$$

Knowing the hypotheses, the next step is the calculation of the sample statistic "t" in order to determine if the result is in the range of acceptance or rejection of the null hypothesis. The sample "t" value is obtained as follows:

$$\mathrm{t_x} = \frac{\overline{\Delta \mathrm{X}}}{\mathrm{S_{\Delta x}}}\ \sqrt{\mathrm{n}} \tag{5}$$

where n is the number of samples used.

For the analysis of the value found for "t" it is necessary to associate it with a tabulated value, thus determining the initial analysis of whether or not to reject the null hypothesis. Student's t-test was used in this way, associated with the number of samples (n) and the significance level. The confidence interval for Student's t-test is found as follows:

$$|\mathrm{t_x}| < \mathrm{t}_{(\mathrm{n}-1;\frac{\mathrm{a}}{2})} \tag{6}$$

Where the "t" Student tabulated value has (n - 1) degrees of freedom at a significance level α. Thus, if the calculated modulus for the sample "t" is less than the value of "t", the null hypothesis is accepted ($\overline{\Delta X} = 0$). In other words the chart can be considered free of significant trends. However if the inequality is not satisfied, the null hypothesis is rejected ($\overline{\Delta X} \neq 0$) and the chart studied may present significant errors at a certain confidence level. According to Galo and Camargo (1994) the fact that there is a trend indicates possible errors in a certain direction due to a number of factors. However if the discrepancies and the direction of the errors are known, their effect can be minimized by performing the procedure of subtracting its value in each analyzed coordinate of the chart.

3.3.2 Accuracy Analysis

According to Nogueira Jr. (2003), the accuracy analysis consists of the comparison of the standard deviation found using the discrepancies between the basemap coordinates and the chart coordinates with the standard error (SE) evaluated using the Cartographic Accuracy Standard (PEC) in relation to the class in which it is desired to evaluate the accuracy of the chart.

The hypothesis test formulated for the accuracy analysis is as follows:

$$\mathrm{Ho:}\ \mathrm{S^2}_{\Delta \mathrm{x}} = \sigma^2 \mathrm{x} \tag{7}$$

$$\mathrm{Hi:}\ \mathrm{S^2}_{\Delta \mathrm{x}} \neq \sigma^2 \mathrm{x} \tag{8}$$

Where $\sigma^2 x$ corresponds to the standard deviation or standard error expected according to the class of the chart in which analysis is desired. Assuming the value of the result generated as being standard error and considering it to be equivalent in the determined horizontal components:

$$\sigma \mathrm{x} = \mathrm{EP}/\sqrt{2} \tag{9}$$

With these initial parameters the chi-square test is applied in order to use statistical methods and determine the class of the chart. The chi-square sample is as follows:

$$\mathrm{X_x} = (\mathrm{n}-1)\mathrm{S^2}_{\Delta \mathrm{x}}/\sigma^2 \mathrm{x} \tag{10}$$

From this calculation the analysis of the statement regarding the hypothesis test is performed where the value of the chi-square table is used according to the following condition:

$$X^2_x \leq X^2_{(n-1;a)} \quad (11)$$

Where the value of the Chi-Square table has (n-1) degrees of freedom and a confidence interval α.

In this way, if the above expression is satisfied, the null hypothesis that the chart meets the established class according to its accuracy is accepted. Otherwise the null hypothesis that the chart meets the established class is rejected. The analysis is performed until the expression is met, characterizing the chart's class according to its accuracy.

3.3.3 Application of the PEC-PCD

To classify the cartographic product it is necessary to determine the quality established by the samples used, where such classifications are directly related to the scale in which it is represented. According to Merchant (1982), the determination of collected samples (reference points) must occur from methods in which the error does not exceed 1/3 of the standard error expected for the class of the chart under analysis. Table 1 below shows the classification of the Planimetric Cartographic Accuracy Standard for Digital Cartographic Products (PEC-PCD) established in the Technical Specification for the Acquisition of Vector Geospatial Data (ET-ADGV, 2011).

Table 1: PEC-PCD.

PEC (1984)	PEC-PCD (2011)	Planimetric PEC	Planimetric Standard Error
-	A	0.28 mm X Scale Factor	0.17 mm X Scale Factor
A	B	0.5 mm X Scale Factor	0.3 mm X Scale Factor
B	C	0.8 mm X Scale Factor	0.5 mm X Scale Factor
C	D	1.0 mm X Scale Factor	0.6 mm X Scale Factor

4 RESULTS AND DISCUSSION

4.1 Determining the Number of Samples

The calculations used to determine the number of samples were developed from equation (1). For the aforementioned analyses, a confidence interval (Z) of 99.50% was used, and the statistical sample population (N) was calculated using the software Dxf2xyz v.2.0, obtaining a total of approximately 24,000 elements for the Topographic Plan of the UFBA campuses, this value being applied in said calculations.

In carrying out the calculations the relative sampling error (ε) was considered to be 1/5 of the sample standard deviation (σ), using the following equation for the calculation of the number of samples:

$$n = \frac{Z^2 N}{(N-1)(1/5)^2 + Z^2} \quad (12)$$

According to equation 12, the number of required samples for the UFBA campuses totals a minimum of 24 samples to be used as control points.

4.2 Obtaining Equivalent Points

The trend and accuracy analyses of this numerical data should be evaluated together in the cartographic product, since the trend analysis, carried out by means of the student t test, allows for the evaluation of the accuracy of the discrepancies around the zero-mean. That is, how accurate is the sample of points collected on the OSM platform in relation to the model cartographic product? The accuracy analysis, performed through the chi-square test, makes it possible to evaluate the accuracy of the samples considering the dispersion (deviation) of these around a certain mean value and, by means of the statistical calculations, assign a scale factor that fits the results obtained.

Tables 2 and 3 show, respectively, the mean and standard deviation values found for the discrepancies in the north and east directions. In the literature, some authors perform the resulting calculation to validate the values obtained using the PEC-PCD. However, in this paper, for a better analysis of the information contained in the map, it was decided to arrange the results separately for the two directions evaluated, thus allowing a better analysis of the results.

Table 2: Mean of Discrepancies.

Mean Deviation	
Delta (E)	-0.197
Delta (N)	-1.680

Table 3: Standard Deviation of Discrepancies.

Standard Deviation	
Delta (E)	2.398
Delta (N)	3.918

This analysis can be verified by observing the values of the discrepancies individually for each point of the sample. For example, in the north direction the lowest sample value was -4.49 m and the highest value was 4.59 m, results shown in tables 2 and 3. In the samples from the eastern direction, discrepancies were also observed, since the lowest value of discrepancy was -7.61 m and the highest value was 7.09 m. Some aspects of the platform are directly related to the heterogeneity obtained in the discrepancies between these samples, explaining the results obtained. The numerical data found for these discrepancies reflects that the scanning of elements by users in the Bing image that feeds the OSM platform occurred at different times, since we do not know in which update the images were inserted or the positional accuracy parameters that feed them. Evidence for this analysis was found by checking the year of digitization of some elements of the study area, noting that there are large temporal discrepancies in the vector files of this platform. Some examples may be cited: Ondina Multi-Sport Square – Last edited: 2013; Federação Classroom Pavilion I Parking Lot – Last edited: 2015; Access road to the Ondina Main Gate – Last edited: 2015; Geosciences Institute – Last edited: 2016; Ondina Arts Square – Last edited: 2017. This temporal variation in the elements contained in the study area and the lack of knowledge about the images in which the scans were triggered make it is possible to indicate certain factors that contribute to this heterogeneity. In addition, the study area, the UFBA campuses, which corresponds to an area of 300,000 m², has undergone extensive changes since 2009 in the elements that make up this setting due to the university remodeling project, with contributions increasing in recent years, showing vector files obtained from different sources and dated to moments throughout a wide time span.

4.3 Trend Analysis

The discrepancies found for the established samples allowed the trend analysis for the same and the identification of the accuracy of these values around the zero mean. From this analysis it was identified that for the studied points in the OSM cartographic product in the area of UFBA, there were error trends towards the north, since the value found for this direction was greater in relation to the t student tabulated value, which indicates that, for this analysis, the mean obtained cannot be considered statistically equal to zero. In turn, for the eastern direction, the result obtained was less than the t student tabulated value, revealing that there are no error tendencies for this direction and that it can be considered statistically equal to zero. Table 4 shows the results obtained for this analysis.

Table 4: T-Student Analysis.

T-Student		
Tabulated (90%)	1.714	
Delta (E)	-0.402	**PASSED**
Delta (N)	-2.101	**DID NOT PASS**

4.4 Accuracy Analysis

By means of the chi-square test, an accuracy analysis was performed for the discrepancies found, evaluating the dispersion of the data obtained from the calculation of the standard deviation of the discrepancies and, consequently, the best scale to fit the OSM cartographic product in the area of study was estimated, making it possible to classify it according to the PEC-PCD. In this analysis the accuracy was evaluated from the scale of 1:5,000 to that of 1:30,000, making it possible to identify at what scale the product is suitable according to the parameter of positional accuracy. Thus, according to the tabulated value of 32.007, corresponding to 90% confidence, this product was evaluated as class C of the PEC-PCD when evaluated in the scale of 1:10,000, class B in the scale of 1:20,000 and class A in the 1:30,000 scale. These results confirm that there was low positional precision in the evaluated product. In other words, there is a relatively high dispersion between the obtained discrepancies, since it was noted that the precision scale was much lower when compared with the cartographic basemap used in this research. Tables 5, 6, and 7 show the values obtained for the scales described respectively.

Table 5: Accuracy Analysis (Scale 1:10,000).

Chi-Square Test (1:10,000)		
PEC-PCD	Delta (E)	Delta (N)
A	91.55	244.31
B	29.40	78.45
C	10.58	28.24
D	7.35	19.61

Table 6: Accuracy Analysis (Scale 1:20,000).

Chi-Square Test (1:20,000)		
PEC-PCD	Delta (E)	Delta (N)
A	22.88	61.08
B	7.35	19.61
C	2.64	7.06
D	1.84	4.90

Table 7: Accuracy Analysis (Scale 1:30,000).

Chi-Square Test (1:30,000)		
PEC-PCD	Delta (E)	Delta (N)
A	10.17	27.14
B	3.26	8.71
C	1.17	3.14
D	0.82	2.18

5 CONCLUSION AND RECOMMENDATIONS

This study made it possible to obtain an initial analysis of the OSM platform in order to quantify the level of positional accuracy of specific features in relation to the reference cartographic basemap in the study area that corresponds to the campuses of UFBA, making it possible to estimate the levels of accuracy and precision of samples for this area and to establish parameters so that information from this platform can be used to assist in reference data, given the inherent difficulty in generating and maintaining cartographic basemaps for different locations.

Given the results obtained and presented, the heterogeneity of the data showed that, for this type of platform, the common sampling techniques mentioned in the literature and in the mapping technical specifications do not provide a sufficient number of samples to determine the pattern of the observed discrepancies. Instead, they are suitable for homogeneous data in which a minimum quantity of samples is sufficient to determine the behavior of the entire statistical population. Thus, for analysis of features in products from collaborative mapping it is necessary to use a larger number of samples in order to obtain more information about the behavior of the data, since, as shown, there are temporal variations in OSM platform elements related to use of Bing image that are unknown to collaborating users, being the object of studies of collaborating users.

In addition, from the sampling process of this data, due to the dispersion obtained, the feasibility of carrying out certain types of statistical analysis that better present the information was evaluated, such as the z test for large samples, the normality test to evaluate whether it is possible to perform a t student test, and Wilcoxon's non-parametric test to evaluate the accuracy of data without the assumption that certain samples come from a normal distribution.

In spite of the inherent characteristics of the samples found and the need to perform other statistical tests and analyses, it is worth noting that a more in-depth verification of how current the data in OSM VGI platforms is may present potential to improve official data, since the fact that data is updated by online users makes it possible to generate information faster. However, more studies must be carried out with the parameter evaluated in this work because despite having a relatively low positional precision, when analyzing individual samples, it was noted that some features presented errors below 0.27 m, as was the case with points located in the university restaurant building and in the Polytechnic School stairway.

Therefore, studies on the efficiency of VGI platforms for feeding reference bases is of fundamental importance in order to generate different references for the cartographic community and for the contribution of society in the generation

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