

Evaluation of positional quality of spatial data generated by UAV for cadastral applications of the municipal cemetery of Monte Carmelo, state of Minas Gerais

Avaliação da qualidade posicional de dados espaciais gerados por VANT para aplicações cadastrais do cemitério municipal de Monte Carmelo, Minas Gerais

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ABSTRACT: By assessing the quality of cartographic products, specifications and techniques emerged with the improvement of regulations and standardization of processes related to national cartographic production digital. In this work, the importance of using statistical techniques in the control of positional quality of spatial data is highlighted. For this, an image acquired by UAV (Unmanned Aerial Vehicle) was evaluated, using as punctual features (homologous points used to check data from reliable information), according to the Brazilian positional accuracy standard (Decree-Law 89,817 of 1984 combined with ET-ADGV) and using as a reference, data obtained through a geodetic survey created by RTK (Real Time Kinematic) positioning. This system is currently the most sought-after equipment on the market due to the precision it offers (approximately 2 cm) and its productivity. After the survey, two situations were evaluated in the assessment of positional quality: the first referring to the use of the geometrically uncorrected image (maintaining only the positional information from the UAV) and the second relating to the use of the geometrically corrected image. From the results obtained, the accuracy of the products was evaluated, and it was observed that, from the homologous coordinates collected by the corrected image, the samples did not show a tendency, revealing to be free from systematic errors, classified in class A. However, when using image data without correction, a C classification was obtained according to the PEC (Cartographic Accuracy Standard).

Keywords: Cemetery; Cartographic Accuracy Standard; Register; Unmanned Aerial Vehicle.

RESUMO: Mediante a avaliação da qualidade de produtos cartográficos, surgiram-se especificações e técnicas com finalidade de regulamentar e padronizar processos relacionados à produção cartográfica nacional, em particular, a digital. Neste trabalho, destaca-se a importância da utilização de técnicas estatísticas no controle da qualidade posicional em dados espaciais. Para isso, avaliou-se uma imagem adquirida por VANT (Veículo Aéreo Não Tripulado), usando as feições pontuais (pontos homólogos utilizados para verificação dos dados a partir de informações confiáveis), conforme o padrão de acurácia posicional brasileiro (Decreto-lei 89.817 de 1984 aliado à ET-ADGV) e utilizando como referência, dados obtidos por meio de um levantamento geodésico executado por meio do método de posicionamento RTK (Real Time Kinematic). Este sistema é atualmente o equipamento mais procurado do mercado em função da precisão que proporciona (aprox. 2cm) e de sua produtividade. Após feito o levantamento, duas situações foram consideradas na avaliação da qualidade posicional: a primeira referente à utilização da imagem não corrigida geometricamente (mantendo apenas a informação posicional do VANT) e a segunda relativa ao uso da imagem corrigida geometricamente. Dos resultados obtidos, avaliou-se a acurácia dos produtos e observou-se que, a partir das coordenadas homólogas coletadas pela imagem corrigida, as amostras não apresentaram tendência, revelando-se serem livres de erros sistemáticos, sendo classificada na classe A. No entanto, ao utilizar dados da imagem sem correção, obteve-se uma classificação C de acordo com o PEC (Padrão de Exatidão Cartográfico).

Palavras-chave: Cadastro; Cemitério; PEC; VANT.

INTRODUCTION

The development and improvement of new technologies positively impact several areas of spatial representation. According to Elwood (2006) apud Machado; Camboim (2019), the map is the best way to organize spatial information, and, to interact with it, the best tool currently available is the Geographical Information System (GIS). As an example of these current applications, the use of GNSS (Global Navigation Satellite System) and Aerophotogrammetry are also mentioned. These applications can attest to how technology has revolutionized products, services and the ways in which they are carried out.

Digital Cartography, in turn, modernized conventional cartography, making it a valuable tool for geographic and environmental studies, making it possible to acquire images through increasingly modern equipment, for example, UAVs (Unmanned Aerial Vehicles) (MENEZES; FERNANDES, 2013).

When it comes to spatial information, quality is related to the product's intended use. Knowing the use of the cartographic product and the admissible uncertainties, it is possible to demand from producers a quality specification, both for the final product and for each production stage, which will bring gains in terms of cost/benefit (NERO, 2005 apud MACHADO; CAMBOIM, 2019)).

Large-scale topographic mapping - in this article, dealing with mapping spatial data generated by UAV for cadastral applications of a cemetery - constitutes the indispensable cartographic base for any GIS application at the municipal level, including those aimed at cadastral mapping (CAMBOIM; SLUTER, 2009 apud MACHADO; CAMBOIM, 2019).

Reference mapping shows the accurate and precise location of natural and artificial features on the Earth's surface and includes intangible objects such as boundaries, water lines, contour lines, and geographic names, at standardized scales (Keates, 1973). The reference mapping, when official, is produced by public bodies designated for this purpose, in compliance with specific legislation and technical standards defined by the National Cartography Commission (CONCAR) (MACHADO; CAMBOIM, 2019).

Such cartographic products are the foundation of any planning, in territorial and engineering terms, to be done. Therefore, if the cartographic base does not meet an acceptable quality standard, the entire following process will be compromised. Therefore, the importance of developing methodologies for evaluating the positional accuracy of spatial data is noted.

Generally, the contents of maps are similar throughout the world, although their reliability and accuracy may vary depending on the techniques and procedures used. To support land use planning and management projects, many countries need to harmonize their land information (PAIXÃO; NICHOLS; CARNEIRO, 2012).

Nichols (1993, p. 35) apud Paixão; Nichols; Carneiro (2012) defines territorial management as the "process of making and implementing decisions about how land and its resources are distributed, used and protected by society". Therefore, having harmonized territorial information helps in updating and accessing territorial information and other benefits, such as: accurate assessment for property taxes, improved government decision-making, security of real property and social inclusion (PAIXÃO; NICHOLS; CARNEIRO, 2012).

Thus, the process for quality analysis, defined for a digital cartographic product, needs attention, as it consists of a cartographic document with different characteristics. Therefore, it is necessary to understand the quality of the spatial data of this product so that it can be evaluated (ROSA, 1996).

This work evaluated the positional quality of a product's data using aerial photographs of the municipal cemetery of Monte Carmelo, state of Minas Gerais, taken with a UAV and points surveyed on the ground with the GNSS (Global Navigation Satellite System) equipment that operates in RTK mode.

For this evaluation, the national standard defined by Decree-Law 89817 of 1984 was used, together with the Technical Specification for the Acquisition of Vector Geospatial Data (ET-ADGV) of 2011, whose technique is associated with the National Spatial Data Infrastructure (INDE) in order to standardize and guide the process of acquiring the geometry of these data (DSG, 2011 apud MACHADO; CAMBOIM, 2019). Thus, two situations were analyzed: use of the geometrically uncorrected image (referenced only with the device's navigation system, keeping only the UAV positional information) and use of the image from the execution of geometric correction.

The hypothesis revolves around the possibility of using the image from the UAV to generate cadastral data, since spatial information is used to extract new data from a product, from the original, in order to meet the ET-ADGV technical specifications.

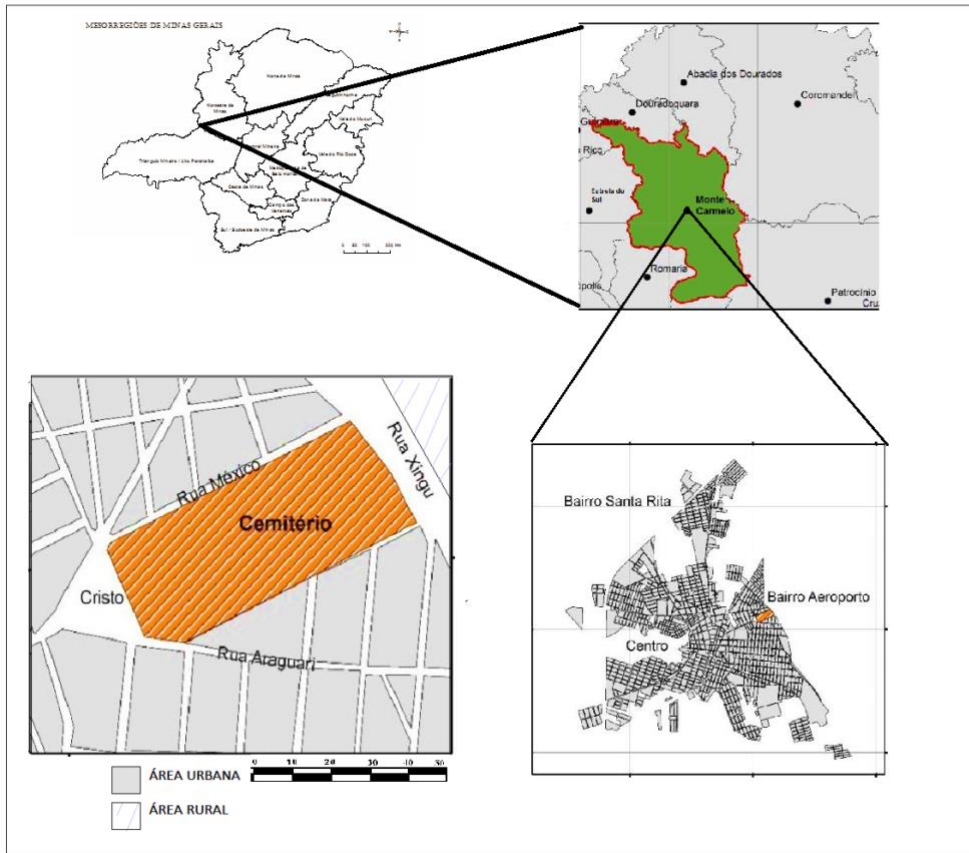
The reason for choosing the area was the need that the administrator had to acquire a cartographic document of the cemetery that had precise coordinates, being able to use it for the control of spaces still available for future burials and cadastral activities of the tombs.

Therefore, the objective of the work was to evaluate the positional quality of the spatial data of the images, generated by the UAV, to aid in the registration of tombs in the Monte Carmelo municipal cemetery and to present results on the use of the images to generate cadastral cartographic bases at 1/1000 and 1/2000 scales in order to meet the ET-ADGV technical specifications using field control points or only those from the GNSS sensor coupled to the UAV.

CHARACTERIZATION OF THE STUDY AREA

The area chosen for taking the photos was the municipal cemetery located in Monte Carmelo, state of Minas Gerais, as illustrated in **Figure 1**.

Figure 1: Study area location map.



Source: Pelegrini, 2017.

THEORETICAL FOUNDATION

AEROPHOTOGRAMMETRY

Aerophotogrammetry, or aerial photogrammetry, are the terms that define the use of images obtained by sensors onboard aircraft as data for the application of restitution techniques in the elaboration of photogrammetric products (DALMOLIN, 2018). Coelho e Brito (2007) apud Jardim; Gomes (2020), is the most used and essential method in obtaining cartographic data of the earth's surface, and consequently the one that has benefited the most from an organization of procedures and parameters.

Tommaselli (2004) apud Dalmolin (2018), states that vectorized images and photogrammetry comprise fundamental aspects to support a digital photo: accuracy, stability and repeatability of the digital process, which harbor precision and continuity in mathematical relationships between pixel in the image and corresponding points on the ground, which can generate a unique product for digital photogrammetry.

For Ribeiro (1995), the aerophotogrammetry technique is the most used for mapping large areas, since this is due to the fact that it presents accurate products at low costs. It also follows the idea that during the flights, when taking the photos, marks are inserted that materialize a specific image system. All photos now have the same marking, making it possible to determine their internal geometry.

However, to understand an aerophotogrammetric process, physical and mathematical concepts, which involve the cameras coupled to the unmanned aerial vehicle, are extremely important.

Photogrammetric cameras are intended to promote photographic images with geometric stability. This characteristic, which justifies the name photogrammetric camera, is what makes the calibration process possible, that is, the determination of geometric parameters that participate in the mathematical model that relates dimensions of the photographed object with its photographic image. (ANDRADE, 1998, p. 26-27 apud JARDIM; GOMES, 2020).

About aerophotogrammetry, the mosaic is an example of a generated document, which consists of a set of photographs that have been cut and technically assembled, in such a way as to make it appear that the whole set constitutes a single photo.

According to ANAC (National Civil Aviation Agency), UAVs are categorized according to their Maximum Takeoff Weight (MTOW) into 3 classes, the first class weighing more than 150 kg, the second weighing between 25 kg and 150 kg and the third weighing less than 25 kg (JARDIM; GOMES, 2020)..

According to Anderson (1982), in practice, these documents are important when a view of the set of photos is required or when a planimetric base is needed and also in the work of locating points in the field.

TREND ANALYSIS

It is extremely important to identify the existence of systematic errors in the data collected, since it indicates the tendency of an instrument to record systematically wrong results. According to Santos (2010), a trend in the assessment of positional accuracy is analyzed since systematic effects can be modeled or even corrected. Furthermore, there are statistical techniques that analyze the presence of trends in spatial data, regardless of their distribution. These calculations are determined using directional mean and circular variance. From there, the checkpoints and their homologous points in the spatial data are analyzed, tracing vectors linking each checkpoint with their homologous (MACHADO; CAMBOIM, 2019).

Traditionally, in the positional quality control of spatial data, to identify the presence of systematic effects, trend analysis is used using Student's t-test, as described in Merchant (1982), Ariza (2008), Nero (2005), Santos (2010) apud Machado; Camboim (2019). However, the t-test assumes that the sample distribution is normal (Montgomery and Runger 2010). However, there are spatial statistical techniques that analyze the presence of trends in the data regardless of the statistical distribution of data. These spatial statistics are Directional Mean and Circular Variance (WONG; LEE, 2005 apud MACHADO; CAMBOIM, 2019).

Most positional accuracy assessments that analyze trends use the Student's t-hypothesis test, as described in Merchant (1982). This test requires the sample of position discrepancies to have a normal distribution. However, there may be cases where the distribution is not normal. In these hypotheses, the solution is to use simple spatial statistics, which return the directional mean of discrepancies and the variability of this mean, thus indicating whether the spatial data has a trend or not (MACHADO; CAMBOIM, 2019).

GEOMETRIC CORRECTION

In order for cartographic precision to be introduced in digital products, it is necessary that the images obtained be corrected, according to some coordinate system. However, the relationship between two coordinate systems used in maps and images can be calculated by defining control points collected in the terrain, which should be recognizable both on the map and on the image.

According to Crósta (1992), the concept of this method establishes the differences in the position of points on the image and on the map. From the differences, image distortion can be estimated and a transformation can be performed to correct the image.

This correction can be obtained through techniques of resampling the pixels of each image in which control points on the terrain are needed, easily identifiable in the cartographic base and in the image to be geometrically corrected.

The record can then be said to establish a relationship between image coordinates and geographic coordinates using simple geometric transformations (usually 1st and 2nd degree polynomial transformations) to establish a mapping between image coordinates and geographic coordinates.

According to Crósta (1992), "The transformation of an image so that it assumes the properties of scale and projection of a map is called geometric correction. This process involves determining between the coordinate system of the map and the image, requesting a set of information to define the pixel centers in the corrected image and, finally, calculating the pixel intensity values."

The raw image coordinates (L: Row; C: Column) are related to the reference coordinates (X,Y) through polynomials of degree n, such that:

$$X = a_0 + a_1L + a_2C + a_3L^2 + a_4LC + a_5C^2 + \dots + a_mC^n$$
$$Y = b_0 + b_1L + b_2C + b_3L^2 + b_4LC + b_5C^2 + \dots + b_mC^n$$

Considering that (X, Y) normally represents the plane coordinates of a certain cartographic projection system.

METHODOLOGICAL PROCEDURES

EQUIPMENT FOR GEODETIC SURVEY

For the geodetic survey, a RTK T500 Topcon GPS with precision provided by the manufacturer of 0.024 meters was used.

The system of this equipment is a type of differential correction that presents high precision, with repeatability of the position obtained through a pair of receivers, since the base remains parked on a point with known coordinates. **Figure 2** illustrates the station used in the field.

Figure 2: RTK equipment used for geodetic survey.



Source: Pelegrini, 2017.

EQUIPMENT FOR THE EXECUTION OF THE FLIGHT

To obtain the images, a Hexacopter X 700 UAV was used, financed by FAPEMIG (Foundation for Research Support of Minas Gerais) to develop research projects at the Federal University of Uberlândia. **Figure 3** illustrates this equipment, and its characteristics are described in **Table 1**.

Figure 3: UAV used for the flight survey.



Source: Pelegrini, 2017.

Table 1: Data of the camera coupled to the UAV used in the field.

Model	Canon Power shot SX 260 x 3000
Image size	4000 x 3000
Focal length	4.5 mm
Pixel size	1.55 x 1.55 μm

Source: Pelegrini, 2017.

AERIAL SURVEY

To plan and execute the aerial survey for this work, the overflow target was first determined, in this case, the municipal cemetery of Monte Carmelo. Therefore, 80% superposition, 12-megapixel spatial resolution, 120-meter flight height for a total of 114 m² of covered area were defined. Thus, there was a reprojection error of only 1.05 pix and a total of 32 images. Thus, the overlapping of photos ranged from 2 to 9 photos, 9 at the central region of the generated model. In **Figure 4**, the lines of flight during the aerial survey are presented, that is, the path that the UAV took when traveling through the area.

Figure 4: Flight lines during image survey.



Source: Pelegrini, 2017.

SURVEY OF CHECK POINTS

Before starting the collection, the positions of the support points in the field were carefully planned for georeferencing the cartographic material, so that they were photoidentifiable, that is, they were found in places of easy recognition on the image, such as, corners on the ground, burial edge points and cross-shaped, paintings which were done in some locations, as seen in **Figure 5**. These points were then tracked using RTK. It is noteworthy that these points were divided into two groups, one used for geometric correction of the image, and the other for product verification. The spatialization of these points is illustrated in **Figure 6**.

Figure 5: Example of the method for selecting points surveyed in the field.



Source: Pelegrini, 2017.

Figure 6: Distribution of points surveyed in the field highlighted in red.



Source: Pelegrini, 2017.

ANALYSIS OF SPATIAL DATA ACCORDING TO DECREE-LAW 89817/84 ALLIED TO PLANIMETRIC PEC-PCD AND SE

The analysis of cartographic precision is composed of two phases: trend analysis (detection of systematic errors by t-test) and precision analysis. These procedures are based on a hypothesis test on the mean and standard deviation of the sample of the discrepancies observed in each planimetric coordinate.

Therefore, the evaluation of positional accuracy is based on the analysis of the residuals between the coordinates of points taken from some cartographic product and their homologous observed in the field (GALO; CAMARGO, 1994) In this case, the product was the image together with its respective collected data and the points surveyed in the field.

Image evaluation was performed by applying the Cartographic Accuracy Standard (PEC), in accordance with Decree-Law 89817/84 and the method proposed by Galo and Camargo (1994) of hypothesis testing was followed: trend analysis and precision analysis.

In addition to evaluating the PEC, this procedure also analyzes whether the product has a trend in the components of the coordinates, indicating the existence or not of systematic errors. Thus, the Decree sets criteria for the classification of cartographic products as to their accuracy and distribution of errors along the coordinates (CRÓSTA, 1992).

As the new PEC-PCD Standard rules, digital products are classified into four classes: A, B, C and D and for scales not covered by the Decree, extrapolations are carried out, maintaining the values provided for in the Planimetric PEC (DSG, 2011)

In **Table 2**, the Planimetric PEC-PCD and the SE (Standard Error) of classes "B", "C" and "D" correspond, in that order, to the "A", "B", "C" classes of the Planimetric PEC provided for in Decree 89817, of June 20, 1984.

Table 2: Planimetry PEC of cartographic products.

PEC (1)	PEC - PCD	1:1.000		1:2.000		1:5.000		1:10.000		1:25.000		1:50.000		1:100.000		1:250.000	
		PEC (m)	EP (m)	PEC (m)	EP (m)	PEC (m)	EP (m)	PEC (m)	EP (m)	PEC (m)	EP (m)	PEC (m)	EP (m)	PEC (m)	EP (m)	PEC (m)	EP (m)
-	A ⁽²⁾	0,28	0,17	0,56	0,34	1,40	0,85	2,80	1,70	7,00	4,25	14,00	8,51	28,00	17,02	70,00	42,55
A	B ⁽³⁾	0,50	0,30	1,00	0,60	2,50	1,50	5,00	3,00	12,50	7,50	25,00	15,00	50,00	30,00	125,00	75,00
B	C ⁽⁴⁾	0,80	0,50	1,60	1,00	4,00	2,50	8,00	5,00	20,00	12,50	40,00	25,00	80,00	50,00	200,00	125,00
C	D ⁽⁴⁾	1,00	0,60	2,00	1,20	5,00	3,00	10,00	6,00	25,00	15,00	50,00	30,00	100,00	60,00	250,00	150,00

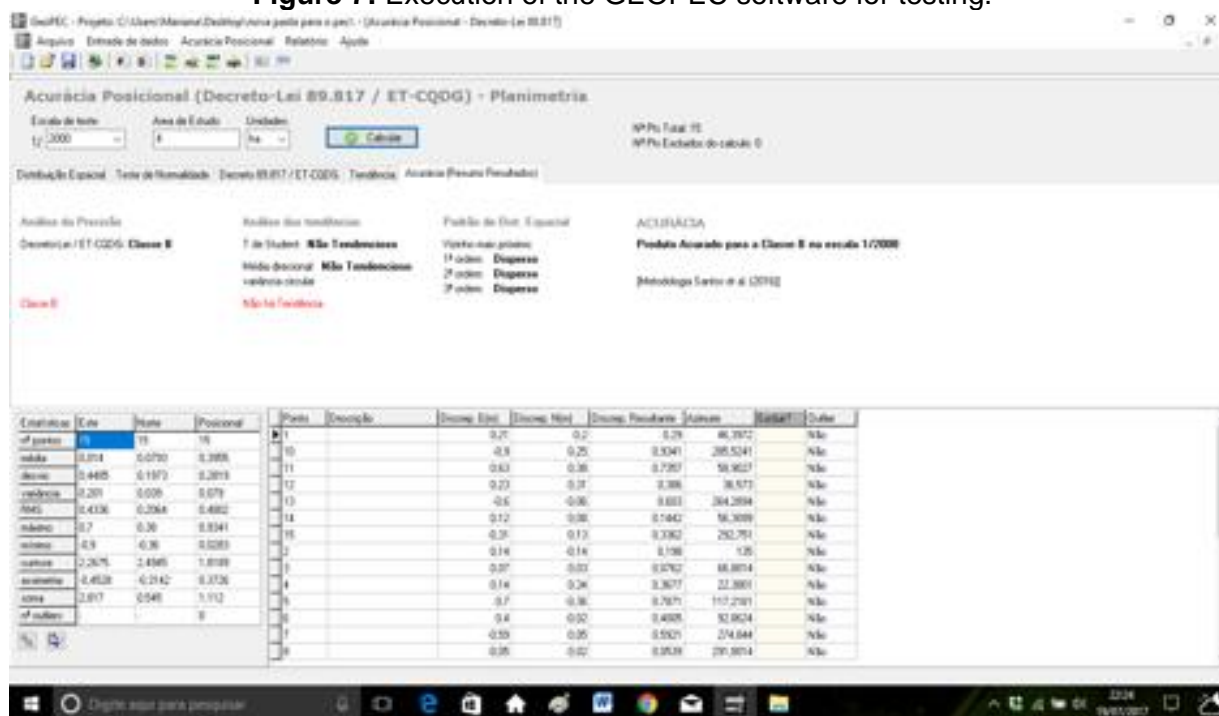
Source: DSG, EB80-N-72. 003.

RESULTS

EXECUTION OF ANALYSIS IN GEOPEC

The GEOPEC software provides easy-to-use tools, so that users can assess the positional accuracy of products according to the standard described in Decree-Law 89817, together with the ET-CQDG of INDE, in addition to the topographic inspection present in NBR 13133. GEOPEC is a software that assesses the positional quality of spatial data, such as maps, orthoimages, vector files, among others. **Figure 7** illustrates this interface.

Figure 7: Execution of the GEOPEC software for testing.



Source: Pelegrini, 2017.

For a better understanding of the analyses, we chose to run 6 types of tests. First, all 30 points surveyed in the field were used in relation to the homologous points selected in both the corrected and uncorrected image. **Figure 7** represented these points. Therefore, 15 verification points (checkpoints) were selected in relation to the homologous in the geometrically corrected and uncorrected image. For this analysis, the choice of these points is justified due to their location, since they correspond to the points at the center of the image, that is, in the location of the study area of this work.

Finally, 5 checkpoints were used in relation to the homologous points selected in both the corrected and uncorrected image. This time, we opted for a smaller number of points so that a final analysis could be performed.

The selection was performed using two points at the edge of the image and a central point, shown in **Figure 8**. The corrected image was then used with the coordinates from the GNSS of the UAV to validate the data using points extracted from the image and their homologous obtained with GNSS - Field for 30, 15 and 5 points. In a second moment, data validation was performed using the checkpoints extracted from this image with the homologous obtained with GNSS - Field for 30, 15 and 5 points, using the control points as checkpoints.

Figure 8: Representation of the 5 randomly selected points in the image.



Source: Pelegrini, 2017.

DATA VALIDATION

For data comparison and validation, together with the coordinates obtained by the field survey, the points in the image were collected. **Table 3** shows the discrepancies between the homologous points of the uncorrected image and the terrain points.

Table 3: Discrepancy in E and N between homologous points of the uncorrected image and the terrain points.

ID	Discrepância E	Discrepância N
P1	-0,35	0,07
P2	-0,54	0,22
P3	0,01	-1,03
P4	-0,59	-0,55
P5	-0,32	-0,84
P6	-0,79	-0,68
P7	0,75	0,89
P8	0,87	0,61
P9	0,48	0,80
P10	0,70	0,12
P11	0,05	0,66
P12	0,66	0,62
P13	-0,86	-0,28
P14	-0,23	-1,29
P15	-0,59	-0,23
P16	-0,11	0,58
P17	-0,14	-0,80
P18	-0,70	-0,44
P19	-1,04	-0,22
P20	-1,35	-0,06
P21	-1,55	-0,15
P22	-1,72	-0,39
P23	0,40	-1,28
P24	0,12	-1,70
P25	-0,17	-2,06
P26	-0,79	-1,65
P27	-0,50	-1,83
P28	-1,10	-1,49
P29	-0,90	-1,41
P30	-1,81	-0,68

Source: Pelegrini, 2017.

As shown in **Table 3**, the discrepancies (without the use of field control) diverge from the discrepancies between terrain coordinates and the image corrected with field control, with smaller discrepancies in the second case. This was expected since the accuracy of the GNSS receiver coupled to the UAV is lower than the accuracy of the receiver used to generate the control points, the checkpoints.

Analyzing the discrepancies in the coordinates of the points using the image without correction with field support, it is noted that the discrepancies between the points located at the center of the cemetery are smaller when compared to those at the edge. It is also observed that the direction of most of these points inside the image follows the same pattern, differently from the others.

This difference between the discrepancies in the coordinates at extreme points and central points is due to the overlapping of scenes during the mosaic generation, since the central region of the product has a greater number of photos (as previously mentioned, it overlaps 9 photos). This consequently improved the adjustment of the image block in these locations, in contrast to the locations with lower density of photos, the edge. Another possible explanation is due to the incidence of radial distortion occurring from the center to the edges of the photograph.

RESULTS OF IMAGE CLASSIFICATION

With the analyses, mean, standard deviation, variance, RMS (Effective Value), among other variables of all coordinates were calculated to, from this, obtain the final classification of the product and check its positional quality. It is noteworthy that the application of such statistical tests was performed using the GEOPEC software, with normal data at the 95% confidence level. Table 4 lists the results obtained.

Table 4: Results obtained using the GEOPEC software. (Number of points, Scale, Accurate product, Precise product, Biased sample, Class (uncorrected image) or (corrected image), YES or NO).

Number of points	Scale	Accurate product	Precise product	Biased sample	Class
30 (uncorrected image)	1:2000	NO	YES	YES	C
30 (corrected image)	1:1000	YES	YES	NO	A
15 (uncorrected image)	1:2000	YES	YES	NO	C
15 (corrected image)	1:1000	YES	YES	NO	C
5 (uncorrected image)	1:1000	YES	YES	NO	C
5 (corrected image)	1:1000	YES	YES	NO	A

Source: Pelegrini, 2017.

From the analyses whose homologous coordinates were collected through the geometrically corrected image, samples did not show a trend, that is, the corrected product did not have systematic errors. On the other hand, when working with the data captured by the uncorrected image, a classification was obtained, but one case had biased samples. It can be seen in Table 4 that when using the 30 uncorrected points, the samples were biased.

As the software runs with the mean of discrepancies, the analyses performed with all 30 points collected were biased due to data redundancy during the calculation

process, since the number of points surveyed in the field at the center of the image is equal to the edges of the image.

It is noteworthy that, through the analyses that used 15 points collected in both images, an accurate, precise and trend-free product was obtained. This is justified by the overlapping of points on the image. Because they are samples of the central coordinates in the image, they had a greater number of photographs for their generation.

CONCLUSION

From the GEOPEC software, positional accuracy norms can be adopted to eliminate subjectivity when detecting how the data are distributed throughout the study area. With this, it is emphasized that, if the points used are well distributed or not, they will be recognized with their due conditions, however, it is important to apply statistical analysis to improve this process.

At first, it is noted that spatial data is not discarded because it is biased, as it can be used to determine areas, distances and angles between features, if the scale is consistent. The main focus of quality control is to evaluate the dataset and present its class for purposes it can be applied.

Finally, it can be concluded that, for the registration of the cemetery, the work achieved the expected objective since it was advisable to use both images (corrected and not geometrically corrected), since all analyses obtained classification and only one of the tests showed a trend in the samples.

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