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Use of Advanced Technologies for Topographic Surveys in Civil Construction

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Abstract

The complexity that has characterized market relations in recent years, with demands for product and process innovation, has even had repercussions on more traditional activities, such as the civil construction segment. Behind only agriculture, the construction industry represents 13% of the global GDP and its volume is US$ 8 trillion per year. However, construction projects often exceed budget by 80%, and deadlines by 20 months. Between 8% and 10% of productivity gains are related to the insertion of technologies (IPEA, 2022). In the field of civil construction, these digital technologies, such as cloud computing, automation, virtual reality and augmented reality, 3D modeling, communication applications and BIM—Building Information Modeling and even machine learning, have been called Construction 4.0. This article evaluates the feasibility of replacing the use of Terrestrial Laser Scanner (TLS) by the use of Unmanned Aerial Vehicles (UAV). For this, it presents a comparison in the use of equipment for carrying out planimetric surveys in civil construction, using as an example the UAV and the TLS—more modern equipment, in addition to the total station—more conventional equipment—for surveying control points. The results show that in the UAV image processing, the RMSE presented a centimeter accuracy (1.93044 cm) for the model. Even if the accuracy of the models generated by TLS is millimetric, it can be considered that the results obtained here were satisfactory, however it is necessary to apply imaging techniques more efficiently to obtain a more accurate product, in order to arrive at millimeter accuracy. Studies on better positioning of targets and georeferencing of models would also be of great contribution to applications in civil construction.

Keywords: Construction 4.0, UAV, 3D Modeling, BIM, Terrestrial Laser Scanner

1. Introduction

The complexity that has characterized market relations in recent years, with the demand for product and process innovation, has even had repercussions in more traditional activities, such as in the civil construction segment (Cavalcanti et al., 2018; Alaloul et al., 2019). Despite being traditional, this segment has undergone several changes in the business model, as a result of important technological advances, requiring companies to adapt to new conditions by incorporating new technologies, professional qualification, materials and developing new processes, considered innovative, resulting in projects increasingly complex (FIRJAN, 2014).

Based on this advance in digitalization, combined with internet technology and other future-oriented technologies, such as the so-called “smart objects” (machines and products), a new change of model in the industry is observed (Lasi et al., 2014). Through these expectations of the future, the term Industry 4.0 was established, which is a concept introduced in 2011 during the Hannover Fair, Germany, announced as the Fourth Industrial Revolution (Madsen, 2019). This new industry concept aims to connect products, production environments, suppliers, transporters and consumers through digitization, automation and artificial intelligence of production processes (Oesterreich & Teuteberg, 2016; Madsen, 2019; Pessôa & Becker, 2020).

In the civil construction segment, these digital technologies, such as cloud computing, automation, virtual reality (VR) and augmented reality (AR), 3D modeling, communication applications and BIM—Building Information Modeling, even machine learning, have been called Construction 4.0 (Craveiro et al., 2019). From the use of technology and the integration of these innovative ideas, a new scenario is created for the construction sector, much more connected and disruptive. Brazil is still in the process of becoming familiar with digitization and its impacts on the concept of Industry 4.0.

Construction 4.0 can be employed throughout a project's lifecycle, from inception to completion, through initiation, planning, execution, monitoring and control, and closure. Companies in the field of Civil Engineering seek new technologies due to the optimization of labor and materials, reduction of environmental impacts and waste generation, as well as the strengthening of quality control, traceability and specialization of labor (Coda et al., 2019).

In the construction industry, the usefulness of technologies such as VR, AR and 3D modeling is extraordinary. According to Nakamura (2018), VR is an interaction technology between a user and an operating system, through 3D graphic resources or 360º images. The goal is to give the user the feeling of presence in a virtual environment, providing a complete immersion in the simulated environment in real time (Masood & Egger, 2019). It can, for example, contribute to the design project, allowing the professional to see the project in 3D in the environment of a work, thus being able to identify possible errors or repairs to be made. In addition, with the simulation in a virtual environment, the client can feel inside his own residence, even before it is built, being able to request changes in the projects in advance.

AR has the opposite purpose of virtual reality. According to Thomé (2019), augmented reality inserts digital elements into physical reality. For example, from footage of an empty room, an application may be able to insert paint colors on the walls so that the user can analyze how such a choice would look before executing it.

3D modeling uses software to create a mathematical representation of a three-dimensional shape. According to Alves (2018), some modeling software allows 3D models to be shared and viewed anywhere, especially at the construction site. In this way, the project can be changed or updated in real time, inaccurate data and calculations can be hastily corrected and the company avoids rework in several steps that would end up generating extra costs and delays in execution.

In this technology environment, we cannot forget BIM. According to Wilson and Heng (2021), BIM is changing traditional construction practices in a broader sense, in terms of people, processes, work, culture, communication and business models. According to Gu and London (2020), BIM involves the application and maintenance of an integrated digital model of all construction information at different stages of the development life cycle in the form of a data repository, including geometric and non-geometric information.

The ability to share information and experience, obtain true cost estimates from the outset, identify problems and implement solutions based on reliable information prior to construction all benefit from saving time, money and achieving a superior result.

Regarding the challenges in the Brazilian context for the use of these technologies, the country faces difficulties such as lack of investment in equipment to incorporate these technologies, adaptation of layouts, processes and forms of relationship between companies in the production chain, as well as the difficulty of creating of new specialties and the development of new technologies (CNI, 2016). In addition, there is a need to adopt relatively quick measures to avoid a competitiveness gap between Brazil and some countries where Industry 4.0 has already started to become a reality.

To obtain the data that will support these technologies, we highlight the three-dimensional survey using Terrestrial Laser Scanner (TLS), which generates a cloud of dense and high-precision points. This product is widely used for taking dimensions in the three orthogonal cartesian axes. Because it uses laser measuring equipment, applying surface scanning, it has a high economic value. In this way, technical and scientific research seeks simplified methodologies for generating models, equivalent to those generated by the TLS (Inocencio et al., 2014; Young & Seonghyuk, 2019).

As alternatives to the TLS, there is the Unmanned Aerial Vehicle (UAV), popularly known as a drone, which through imaging and specific software is capable of generating three-dimensional models equivalent to the models generated by the TLS. However, Fonseca e Silva and Maia Gomes (2020) in their results points to the need for further research with regard to positional precision and accuracy, the feasibility of applying UAV imaging in civil structures, as well as producing equivalent end products of this technology (digital terrain model and point cloud).

To solve issues like to reduce the digitization time and costs while maintaining a high coherence between the physical artefact and its digital counterpart, in a context where the purpose is to massively digitize complex objects in their original setting by minimizing the impact, several methodologies are being discussed to improve the efficiency of digitization regarding image capturing, 3D model creation, scaling and mesh editing.

This study is corroborated by Medeiros, Figueira and Vasconcelos (2022), where they highlight that, despite the merit of the scientific community turning to studies on AR in recent years, joint efforts are needed to solve the challenges faced by technology, such as the parallax, hardware limitations, the high consumption of time to configure the markers, data storage limitations, poor georeferencing and inaccurate tracking of the environment, in order to make the use of AR even more assertive, efficient and accessible in the construction site.

In this context, the research question is how UAV can replace the use of TLS, obtaining accurate results. This article aims to evaluate the feasibility of replacing the use of a three-dimensional TLS by the use of UAV in three-dimensional surveys for civil construction. For this, it presents a comparison in the use of equipment for carrying out three-dimensional surveys in civil construction, using as an example the UAV and the TLS, in addition to the total station—more conventional equipment—for surveying the control points.

With the results obtained in this comparison, it is possible to manage the positive and negative points of each equipment, where each one is more viable depending on the case to be studied. In its development, research was carried out on the functioning of the equipment mentioned above, as well as the precision of each one and the recommendations contained in the norms regarding the acceptable standard deviations. After collecting this information, for the methodology, a field study was carried out in a real work still in progress within the municipality of Gravatá—PE, where it was possible to use the total station together with the Global Navigation Satellite System (GPS/GNSS) RTK—auxiliary equipment, TLS and VANT to carry out the same planimetric survey, and with the use of software, results were obtained that served as comparison instruments.

1.1 Perspectives of Imaging Technologies in Brazil

The use of TLS has expanded a lot in recent years in the field of graphical and metric documentation of objects, mainly because it is a non-destructive and non-invasive technique, which does not involve direct contact. TLS is Remote Sensing equipment that make it possible to collect a large number of data from the observed surface, with high precision and a fast acquisition rate (thousands and even millions of points per second (Inocencio, 2014; Kerle, 2019).

The basic operating principle of the TLS is to measure the time required for a laser pulse to travel from the transmitter to the reflective surface of the target and back to the receiver. The light beam emitted by the equipment travels through the atmosphere and interacts with the target object. The constituent atoms and molecules of the target reflect or absorb electromagnetic radiation and its backscattering gives rise to remote laser detection (Becker, 2019). The files generated by TLS is based on a structure where the coordinates of the points in space (x, y, z) are stored, the laser pulse return intensity value (I) and, if available, the values from the digital camera attached to the equipment. The final product of a scan is a cloud of points with spatial coordinates and their corresponding intensities, forming a 3D image of the scanned structure (Ferraz, Souza, & Reis, 2016; Becker, 2019).

This technology is not recent in civil construction and has been used, among other applications, to estimate the deformation of arches and vaults, based on the symmetry of cuts obtained along the vault guideline (Armesto et al., 2010; Cintra, 2017) , obtaining as-built designs (Bosché, 2010; Klein, 2012; Miranda, 2020; Gouveia, 2021), automatic recognition of surface damage related to mass loss (Teza, Galgaro, & Moro, 2009), scanning for reconstruction models of building facades and pathological manifestations in materials that make up the construction of buildings (Pu & Vosselman, 2009; Ballesteros, 2020; Ballesteros & Lordsleem Junior, 2021), efflorescence in granitic rocks on the walls of buildings, through the images generated in the scan (Armesto-González et al., 2010) and even to detect the proliferation of mosses in reinforced concrete structures (González-Jorge et al., 2012).

To use the UAV as a solution, it is necessary to apply the principle of photogrammetry and aerial surveying. Objectively, photogrammetry is the science or art of obtaining reliable measurements through photographs. In order to analyze the data obtained in photogrammetry, it is necessary to know the phototriangulation technique, which is presented as a technique that helps in the mathematical interpretation of photographs. The aerial survey, on the other hand, can be described as a set of air or space operations for measuring, computing and recording terrain data using specific sensors, consisting of an aerospace phase for capturing and recording data and a phase that refers to the data processing (Macedo et al., 2020; Sobrinho, 2021).

In order to measure and confirm the results, it is necessary to implement control points on the ground, these points are targets or georeferenced objects on the ground that will appear in the aerial images, that is, photo-identifiable. These control points are used to correlate the image coordinate system with the terrain coordinate system. They are reference points on the ground that are used in the post-processing of the images to increase the accuracy of the final products generated (Neto, 2015; Cintra, 2017; Malik & Guidi, 2018). In summary, they are applied to increase the accuracy of your aerial survey.

To collect the coordinates of the control points, total stations and the GPS/GNSS are used. Cintra (2017) defines a total station as an equipment created from the integration of an electronic distance meter germinated to an electronic theodolite. The GPS/GNSS is a method that uses satellites positioned in the earth's atmosphere to georeferenced points, thus determining the coordinates and altitude of any point (Silva, 2017). GPS/GNSS-type equipment allows you to obtain the precise position and geographic location of points anywhere by means of artificial satellites. The collection of coordinates can be done using the RTK (Real-Time Kinematic) technique, which applies a connection to a special radio modem, in this way the GPS/GNSS system can be operated in real time, that is, the coordinates do not need to be post-processed.

As a result of the application of the scanning and imaging technique, the aim is to obtain products of the Digital Elevation Model (DEM) type, which is a numerical data structure that represents the spatial distribution of a quantitative and continuous variable. Still in relation to the DEM, this can be considered in two perspectives, the Digital Terrain Model (DTM) which is the altimetric representation of the terrain surface, excluding obstacles that prevent the direct visualization of the surface, in this way it represents the real surface of the terrain without elements that influence the reflectance of the pixels (Malik & Guidi, 2018) and the Digital Surface Model (DSM) which is the altimetric representation of the terrain surface, including all obstacles. The DSM represents the land surface plus any existing objects on it, so if there are vegetation formations or buildings, the represented surface will be the top of these features (Malik & Guidi, 2018).

1.2 Advantages of Innovative Technologies

The construction industry represents 13% of global PIB, second only to agriculture, its volume is US$ 8 trillion per year. However, it is extremely inefficient. Commercial construction projects typically exceed budget by 80%, and deadlines by 20 months (IPEA, 2022). On paper and on the computer, everything looks great, but in the hustle and bustle of the construction site, everything is different. In this gap between plans and reality, three out of eight trillion dollars are lost in recalculations, changes and schedule deviations.

According to Santos (2019), 8% to 10% of productivity gains are related to the insertion of technologies. Mapping technologies using UAV or TLS provide easy access to large or hard-to-reach facilities, as well as complex or large facilities. They are able to provide aerial photography data, map information and images used for: surveying, building inspections, provide visual materials for customers and employees, monitoring the progress of works at the construction site, security control and mappings.

In the case of construction projects, 3D models can reveal construction design errors due to their ability to capture large amounts of data in a relatively short time, which leads to significant cost savings as well as necessary design costs. for these activities. New technologies guarantee project time, budget and accuracy. Furthermore, from the high-quality images produced, 3D surfaces (DSM) or terrain (DTM) models can be created.

2. Materials and Methods

To achieve the proposed objectives and test the experimental hypotheses, a study was carried out in 4 phases. In the first step, the study area was defined. The second phase, the field phase, consisted of implanting points in the field, for dimensional control, using the Total Station and collecting these points with precision equipment and carrying out the imaging through the UAV and the TLS.

In the third phase, the data collected in the field were treated and analyzed in the laboratory, using software. In the last phase, a ranking of the two technologies according to accuracy was elaborated. The methodology developed in this study is made up of four steps, described in the flowchart shown in Figure 1.

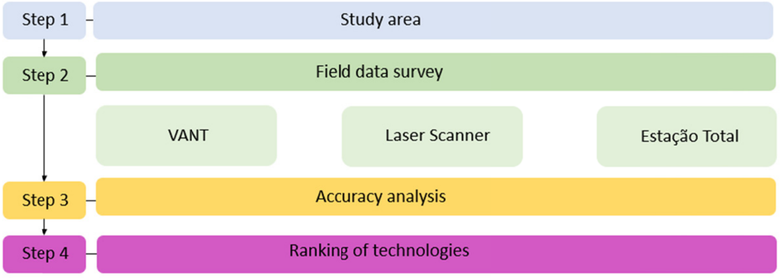

Figure 1. Methodology developed in this study

2.1 Step 1—Study Area

The area was selected based on the availability of the Guandalini team to monitor the survey with the TLS. It is a residential property, located in the city of Gravatá (Figure 2). The municipality of Gravatá is located in the rural area, 81 km from the capital of Pernambuco, Recife (Figure 3). Its population, according to IBGE estimates for 2021, was 85,309 inhabitants (IBGE, 2021), spread over an area of 506,946 km² (IBGE, 2022). During festivities such as São João and holidays, many inhabitants of the Metropolitan Region of Recife (RMR) travel to Gravatá, causing the number of people in the city to increase momentarily.

As it is a transition region between the Sertão and the Zona da Mata, several specimens of both the Atlantic Forest and the Caatinga can be found. Gravatá has a semi-arid climate (Bsh type in the Köppen-Geiger climate classification) (MIN, 2005), influenced by the Serra das Russas, which, due to its altitude, causes orographic rainfall, preventing more abundant rainfall in the municipality. The average annual temperature is 22 °C, with lows reaching 15 °C in the coldest months, while in the hottest season maximum temperatures can reach close to 30 °C.

Figure 2. Study area

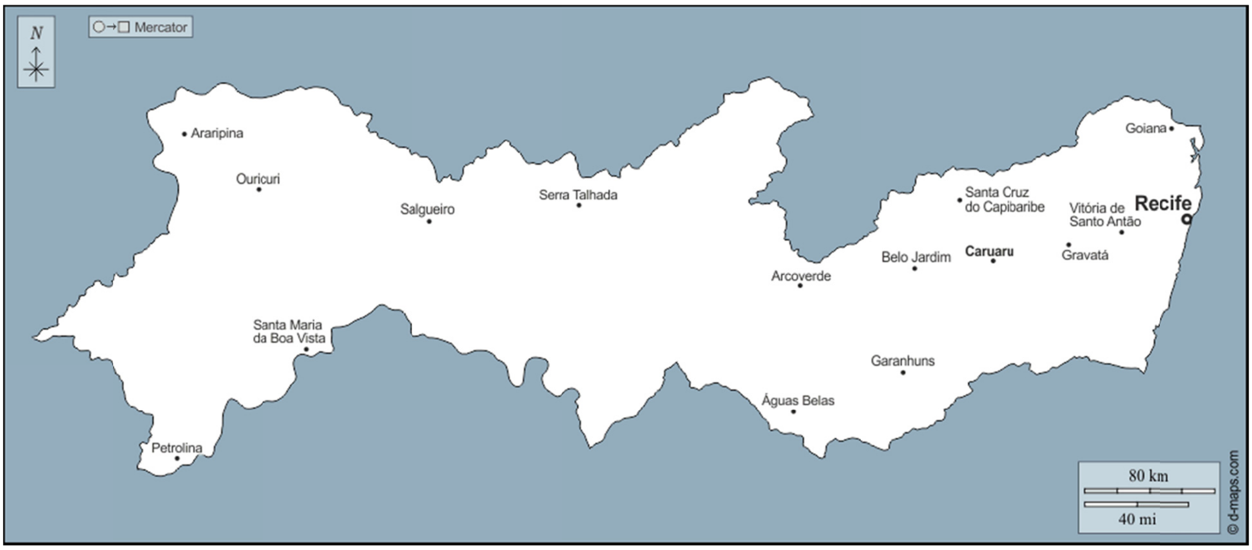

Figure 3. Gravatá-PE (IBGE, 2022)

2.2 Step 2—Field Data Survey

This step used total station and RTK GPS/GNSS equipment. The total station used was a FOIF brand, model RTS 102, with an angular accuracy of 2" and a linear accuracy of 2 mm + 2 ppm, and the GPS RTK by the SOUTH brand, model Galaxy G1 (L1L2), with a horizontal RTK accuracy of 8 mm + 0.5 ppm and 15 mm RTK vertical + 0.5 ppm.

The survey with a total station was carried out as follows: parking the total station at station E1, using station E0 as reference, from E1 the control points and the limits of the back of the land were irradiated. Once this stage was concluded, the total station was parked at E0 and the device was oriented at the E1 station, and from there the points on the boundary of the terrain and the control points on the front of the terrain were irradiated. The irradiations were made using prism with direct reading in the work.

After obtaining the georeferenced coordinates of E1 and E0, the data were processed in the Autocad Civil 3D software, where the main traverse and all the irradiations were calculated, and through this process the precise coordinates of all the vertices of the work were obtained, including the control points.

The equipment used as a UAV was a DJI Mini 3 Pro (DJI RC) (GL), equipped with a 20-megapixel camera and a precision GPS/GNSS kit (PPK—Post-Processed Kinematic) Emlid M+ (L1) with its respective Emlid RS base (L1). Although it is not the most used model in the literature, it was chosen because it is a low-cost device.

The overflight with the UAV was carried out with the aid of the Matterport MAP Pilot application, the mission was of the Oblique type at 25 m in height, with the camera directed at 60° in relation to the nadir. The overlapping of the photos was 89 and 90% (overlap, sidelap).

As TLS, the Matterport Pro2 was used, which has a 3D sensor of structured light (infrared), 20 seconds of capture time per scan, 99% accuracy within range and a maximum range of 4.5 m. Depth resolution is 10 points per degree (3600 points at the equator, 1800 points at the meridian, about 4 million points per panorama).

2.3 Step 3—Accuracy Analysis

The data collected in the field were treated and analyzed in the laboratory, using software such as Guandalini PPK, AutoCad Civil 3D, Agisoft Photoscan, in addition to Map by Matterport. In this step, the topographic data of the control points collected in the field were treated in the AutoCad Civil 3D software and their coordinates corrected. The precise coordinates of the photos, which were obtained through the GPS/GNSS onboard the UAV (Emlid M+), were treated and corrected through the Guandalini PPK software, while the images collected in the field were treated in the Agisoft Photoscan software, in which, through algorithms, applies to the phototriangulation technique: aligning, georeferencing and generating the specific products of aerial photogrammetry.

The photographs obtained in the aerial survey (445) were processed with reference to the 10 control points surveyed in the field, and the final product was an orthophoto in '.tiff' format, georeferenced, which was imported into the AutoCAD civil 3D software.

The use of technological equipment, such as the total station, for measuring measurements within civil construction requires some care so that the results obtained do not suffer variations that do not meet the pre-established standard deviations in NBR 13133 (Matos, 2018). What differs them is the way they are handled, and with the laser scanner and the total station, many processes are done manually, for example, the correct use of the prism in the total station, which needs to be positioned so that the emitted laser through the device directly hit your target. In addition, it needs to be level with the ground, which is why it usually has a spirit level in its structure, which makes the operator precise when holding it. With drones, most processes are programmed through a device, which can be the user's own smartphone, and thus the drone does the service automatically according to the programming made, which can leave margins for error if the programming is not done correctly. correctly (Sobrinho, 2018).

Matos (2018) shows that the technical unpreparedness to use this equipment can directly interfere with the final project, because with the mistakes made, it may be necessary to redo the fieldwork. In addition to the technical preparation for their use, it is also necessary that the conditions of the device are in accordance with the compliances so that the work is carried out with quality.

According to Rebelo (2019), no matter how hard you try to reduce and even eliminate errors, they always happen. The most common errors occur on three occasions, errors due to natural factors such as wind, humidity, fog, etc.; errors due to instrumental factors, which refer to defects in the device used; and errors due to personal factors, which, as previously mentioned, occur when the operator does not perform the work accurately. The latter may still be related to the user's sensory issue, such as touch and vision, each of which has its own annuity.

Still within the scope of possible errors, Matos (2018) showed in his work that with the use of the total station the influence of the ambient temperature interferes with the results obtained, and the heat of the sun acting directly on the device caused the measurement to suffer a error of approximately 3cm, not being within the standard established by the norm considering the type of device used (FOIF station model RTS/OTS 685). As previously mentioned, NBR 13133 provides a table regarding acceptable standard deviations in the use of total stations, according to the class of each equipment.

the results obtained with UAV also depend on a number of factors to be as accurate as possible. The lack of knowledge in its handling and the interference of external factors are examples of these factors. According to Xavier (2020), for the results to be more accurate, it is necessary to combine some equipment together with the drone. The RTK GPS is the equipment that helps the drone to carry out the surveys, obtaining the coordinates (X, Y and Z) of the points of interest. Also, according to Xavier (2019), the GPS/GNSS system integrated into the drone does not have good accuracy for aerial surveys, and can generate errors within a radius of 5 to 10 meters from the point of interest depending on the type of device used.

Arias (2017) points out that another factor that directly interferes with the results obtained with drones is the solar trajectory, because depending on the time of day, the shadow area can make it difficult and generate errors in image processing.

3. Results

The search results are presented below.

3.1 Survey and Analysis of Control Points

The control points, to verify the accuracy, were surveyed using the Total Station and are shown in Table 1, together with the RMSE resulting from the processing.

Table 1. Coordinates and RMSE of the control points

Ponto	E (m)	RMSE (m)	N (m)	RMSE (m)	Altitude (m)	RMSE (m)
1	217.719,69		9.091.755,16		489,755	
2	217.736,46	0,0015	9.091.750,23	0,0154	489,695	0,0251
3	217.723,48	-0,0102	9.091.750,51	-0,0082	489,485	0,0060
4	217.710,62	0,0095	9.091.746,77	-0,0007	489,986	0,0115
5	217.721,17	-0,0012	9.091.743,59	-0,0082	489,193	0,0060
6	217.726,53	0,0205	9.091.737,06	0,0037	489,369	0,0011
7	217.733,75	-0,0017	9.091.734,66	0,0055	489,510	0,0229
8	217.738,42	-0,0027	9.091.732,33	-0,0002	489,384	-0,0059
9	217.705,89	0,0125	9.091.730,70	0,0158	489,131	0,0460
10	217.706,84	-0,0021	9.091.729,59	0,0048	489,169	-0,0063

At the end of processing, a report was generated with the Root Mean Square Error (RMSE) values of the points. This RMSE is the root mean squared error of the difference between the prediction and the actual value and explicitly represents what various methods tend to minimize (Lopes & Barbosa, 2020). The result of adjusting the three-dimensional model, using the control points, can be seen in Table 2.

Table 2. RMSE of control points

Number	X error (cm)	Y error (cm)	Z error (cm)	XY error (cm)	Total (m)
10	1.22324	0.87940	1.99074	1.32014	1.93044

X – Easting Y – Northing Z - Altitude

The processing resulted in a three-dimensional model, point cloud, with 7,490,386 points, that is, a density of 1,706,238 points/m². Figure 4 shows the three-dimensional model obtained through imaging.

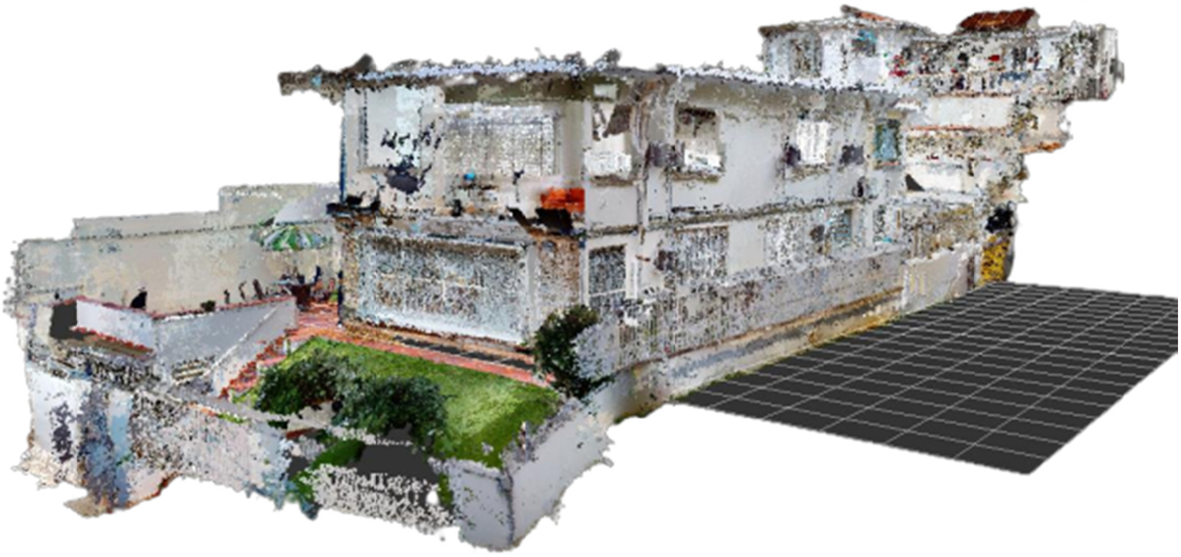

Figure 4. Three-dimensional model obtained through imaging

The processing for acquiring the corrected coordinates of each photo, using the Guandalini PPK software, showed an average standard deviation of 0.00325 m in the horizontal components and 0.01447 m in the vertical component. The coordinate values were exported to Agisoft Photoscan, respectively for each photo taken in the field. This result helps in the dimensional analysis and accuracy of the model, based on the points collected in the field, and this analysis is the main source of data to validate the raised hypothesis.

3.2 Accuracy of the Models

When dealing with the accuracy achieved in the processing, the RMSE presented a centimeter accuracy (1.93044 cm) for the model. Even though the accuracy of the models generated by TLS is millimetric, it can be considered that the results obtained here were satisfactory, as this is a first model, used only as a feasibility test. It is noteworthy that, alone, the worst accuracy was observed in the vertical component (1.99074 cm) which indicates an important verification point for definitive processing.

Another comparison can be seen between the dimensions taken between the centers of the targets (control points) both in the three-dimensional model, still within Agisoft Photoscan, and in the cloud of points in Autocad Civil 3D. Comparison values are shown in Table 3.

Table 3. Variations between the distances of the control points

From the Point	**To the point**	**Distance (m) CAD**	**Distance (m) Agisoft Photoscan**	**Variation (m)**
1	2	9,232	9,244	0,012
2	3	14,213	14,237	0,024
3	4	7,243	7,249	0,006
4	5	15,654	12,665	0,011
5	6	4,562	4,554	-0,008
6	7	17,523	17,514	-0,009
7	1	12,814	12,827	0,013
2	8	31,035	31,037	0,002
8	9	14,297	14,302	0,005
9	7	27,417	27,412	-0,005
-	-	-	**RMSE**	**0,00013**

It is worth mentioning that the resolution of the TLS image can currently be millions of points, thanks to the sophistication of the image treatment and modeling software, while the UAV offers a resolution of hundreds of points. Although the increase in the number of points increases the operational cost of modeling, this time can be optimized by processing data in the cloud. Table 4 presents a brief comparison between these two methods.

Table 4. Comparison between TLS and UAV

Characteristics	**TLS**	**VANT**
Equipment Accuracy	Millimeter	Centimeter
Resolution	Million points	Hundreds of points
Equipment Cost	Tens of thousands	Thousands
handling skill	Medium/High	Low
Portability	Bulky	Not bulky
3D model accuracy	Depends on the equipment	Depends on processing software
Generation of 3D models	Automatic capture	Postprocessed
Environmental challenges	Reflectivity, surface texture, target movement	Repetition, flight conditions, angle of view
Equipment limits	-	Does not fly over indoor areas

4. Discussion

It was evident in this study that the ambient lighting is an important issue to be evaluated in the planning and execution of the imaging. The shaded locations in the model showed greater deficiency of details for both equipment.

For aero photogrammetry, flight altitude is an item of great relevance. In this way, it could not be different for the final result of UAV imaging. The richness of detail in the final model directly depends on the amount of detail observable in the photos, that is, it is necessary to correctly equate the camera resolution ratio with the flight height and the desired richness of detail.

Another issue regarding the use of the UAV in this type of application is that it is restricted to use in uncovered environments, preventing its use in closed and covered environments, due to the need for visibility for the GPS/GNSS, both for navigation of the drone and the on-board precision one (PPK Emlid), while the LST model adopted allows imaging in closed environments with low light.

Equating the point cloud generated by UAV imaging with a probable modeling using TLS in an equivalent area, the number of points generated is greater, but even so it is reasonable to inform that the number of points to be generated in modeling by imaging can be adapted, being defined by the user while executing the processing in Agisoft Photoscan. It is noteworthy that the increase in the number of points in the processing phase is due to interpolation processes and does not represent new points obtained in the mapped object, which can compromise the accuracy of the survey.

Still on a direct comparison between the methods, regarding the time taken in the field information, the time in the imaging method was 58 minutes, from the implantation of the points until the end of the overflight. In the LST scan, the time was 3 hours and 18 minutes. This shows that the imaging method presents greater simplicity in its field conception.

In terms of processing, imaging made great demands on the machine (computer) used. Even though it is a specific equipment for processes that demand high processing capacity (Central Process Unit—CPU) and memory (Random Access Memory—RAM), this processing required 17 hours in the Depth Map and 9 hours and 27 minutes in the Dense Point Cloud, remembering that such processes were continuous, without turning off the machine during this entire period. Still comparing with the LST, the processing of the points obtained with the laser scanner demanded 5 hours and 30 minutes.

It was characterized that in the imaging method the final result is intrinsically linked to the ability of the software algorithms to resolve possible dimensional errors in the model, given that the algorithm interprets repeated overlapping of images of the same scenario, seeking homologous points. In LST scanning, however, this resolution is directly linked to the robustness and precision of the laser equipment and not to the processing software.

In order to carry out modeling as a basis for projects in civil construction, it is clear that it is necessary to apply imaging techniques more efficiently to obtain a more accurate product, in order to reach millimetric accuracy. Also studies on better positioning of targets and georeferencing of models would be of great value.

As observed in the referenced studies, the TLS is able to detect moisture, biodeterioration and cracks, pathological manifestations, in addition to allowing the visualization of dimensional changes and deformations in the order of a few centimeters. By enabling the visualization and scanning of a structure without direct contact with it, with a range of meters and even kilometers, the LST would be an option for inspections in civil construction. Image processing techniques and classification algorithms can also be used to create a pattern for the incidence/intensity/amount of damage to structures, which in current methodology depends on the inspector's qualitative criteria.

This study is in its initial phase and opens up a range of opportunities in terms of scientific development and innovation, bringing together the Remote Sensing area and Civil Construction. It is believed that with the advancement of the technological capacity of the equipment used here together with their respective software, 3D modeling through these new tools, replacing an LST, will soon have a viable and reliable methodology to apply in three-dimensional modeling.

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