World Academy of Science, Engineering and Technology
International Journal of Civil and Architectural Engineering
Vol:15, No:5, 2021

Geometric Contrast of a 3D Model Obtained by Means of Digital Photogrametry with a Quasimetric Camera on UAV Classical Methods

Julio Manuel de Luis Ruiz, Javier Sedano Cibrián, Rubén Pérez Álvarez, Raúl Pereda García, Cristina Diego Soroa

Abstract**—**Nowadays, the use of drones has been extended to practically any human activity. One of the main applications is focused on the surveying field. In this regard, software programs that process the images captured by the sensor from the drone in an almost automatic way have been developed and commercialized, but they only allow contrasting the results through control points. This work proposes the contrast of a 3D model obtained from a flight developed by a drone and a non-metric camera (due to its low cost), with a second model that is obtained by means of the historically-endorsed classical methods. In addition to this, the contrast is developed over a certain territory with a significant unevenness, so as to test the model generated with photogrammetry, and considering that photogrammetry with drones finds more difficulties in terms of accuracy in this kind of situations. Distances, heights, surfaces and volumes are measured on the basis of the 3D models generated, and the results are contrasted. The differences are about 0.2% for the measurement of distances and heights, 0.3% for surfaces and 0.6% when measuring volumes. Although they are not important, they do not meet the order of magnitude that is presented by salespeople.

Keywords**—**Accuracy, classical topographic, 3D model, photogrammetry, UAV.

I. INTRODUCTION

DIGITAL photogrammetry has been applied for surveying uses since 1980 approximately, with frankly good results in terms of accuracy and performance. Digital Terrain Models (DTM) have been developed from digital pictures taken from Unmanned Aerial Vehicles (UAV) since approximately 2010 [1]. It is worth mentioning that taking images from a drone has many advantages, such as the easiness to obtain aerial vehicles, the lower requirements for the digital camera, the adjustment of the flight to real necessities [2], etc.

As the activity of drones is increasingly expanding in the field of engineering, more specifically in photogrammetry, and given the fact that there are not clear studies that indicate which method is the most accurate, the need of comparison of their effectivity with respect to the classical methods that have been applied so far arises [3]. The main aim of this work is the comparative study of an existing object in the territory using the diverse procedures to develop the topographic survey, in order to contrast the accuracy of photogrammetry with low altitude drones [4]. Nowadays, there are similar studies that consider image overlapping [5], image georectification [6], comparison of results with software [7], or 3D point positioning of points [8], but they do not propose the real contrast between measurements made with the models that are subjected to analysis. Due to this, the development of a topographic survey with classical methods and the use of a Topographic Station are proposed and, after that, through the application of aerial photogrammetry with a quasimetric camera and a drone flight, the generation of a model with the images that are thus obtained.

Among the most prominent uses of drones, its application for the measurement of distances, surfaces and volumes can be presented [9]. To this effect, the topographic survey will be located in an industrial area, where the buildings take great surfaces and the distances to be measured are clear and long. The results obtained with both methodologies are applied to set a series of advantages and disadvantages that differ between them, concluding which is the most adequate for the development of this study. In this sense, the selected object is an industrial facility that is located in the industrial park of Tanos-Viérnoles (Cantabria, Spain), and more specifically, the industrial warehouse of Agro Cantabria. As it can be appreciated in Fig. 1, it meets all the requirements that have been previously defined.

Fig. 1 Object used for the geometric contrast

II. INSTRUMENTAL AND METHODOLOGY

A. Survey with Classical Topographic Methods

Classical Topographic Methodologies are based on capturing information in a reference system, and measuring angles and distances for their subsequent representation by means of coordinates [10], [11]. A previous methodological planning of the work to be developed is required for the development of a topographic survey, in order to optimize the

Julio Manuel de Luis Ruiz*, Javier Sedano Cibrián, Rubén Pérez Álvarez, Raúl Pereda García, Cristina Diego Soroa is with School of Mining and Energy Engineering of University of Cantabria, 39316 Torrelavega-Cantabria, Spain (phone +34 942 846 535, *e-mail: deluisj@unican.es).

resources, obtain the best results, and fulfil its objectives.

a) Survey Points Network

The survey points network is the fundamental line of the topographic survey, and it comprises a series of vertices from which all the other points required for the development of the survey are observed. The survey points network has been developed according to two requirements:

- GPS surveying (Rapid Static Positioning), materialization of the Reference System for the Spanish cartography, ETRS89 and UTM H30N.
- Topographic Station surveying (Method of itinerary), starting from the aforementioned survey points, an open traverse is framed, for its checking and compensation.

Fig. 2 shows the survey points that were obtained with GPS in yellow, and those obtained with Topographic Station in green.

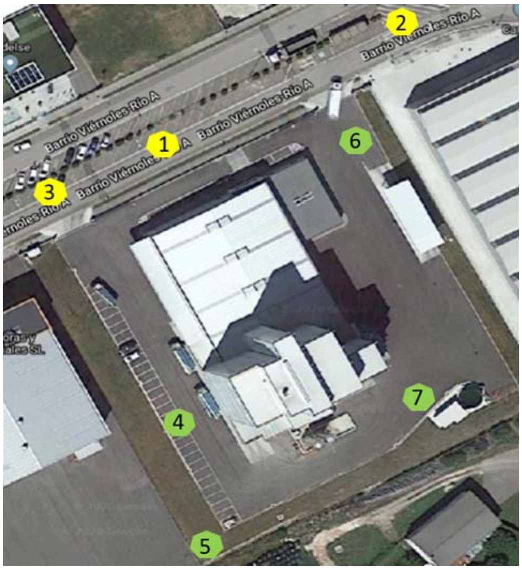


Fig. 2 Survey Points Network

b) Filling Network

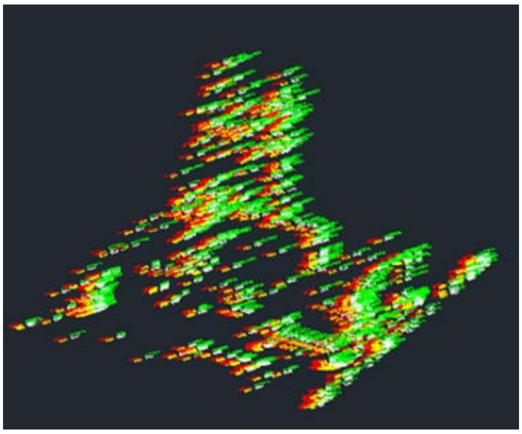
The filling network requires placing the Topograhic Station on the mentioned survey points, so as to radiate from them all the points that are fundamental for a proper definition of the space of the industrial warehouse selected. It is worth noting that it was necessary to radiate about 300 points, whose coordinates were subsequently calculated with conventional software.

The traverses were made by applying the Bessel rule to eliminate the systematic errors of the device. For the elaboration of the DTM, a sketch of the points that were observed from each survey vertex was drawn, indicating them in photographs of the warehouse. This greatly facilitated the works of representation.

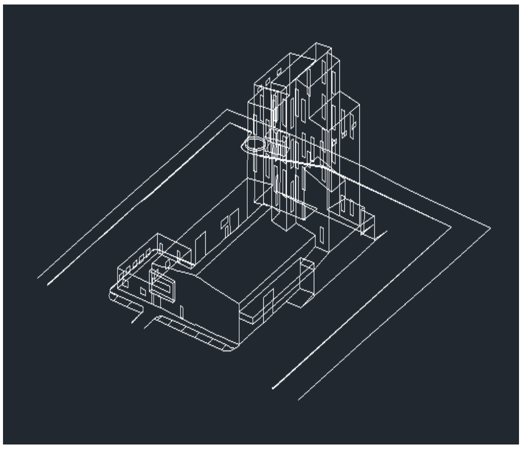
c) Generation of the DTM

After determining the coordinates of the point cloud that geometrically defines the warehouse, this point-cloud can be imported to any of the conventional software programs that permit the development of DTM. In this case, the open source software Topocal was applied. Fig. 3 (a) shows the point-cloud that was applied for the generation of the DTM.

After the data import, the application allows plotting polylines that connect points, either manually or automatically with the same code, which makes it very effective when joining the points that define a same line. After obtaining the polylines, the model is exported to Autocad [12], where the work can be eased by generating layers for the different points that comprise the warehouse, as it facilitates their editing processes. Only the layers that are under edition in a certain moment will be visible. In the same way, a different color has been assigned to each layer for a fast recognition of the kind of point. When this process is completed, a wireframe structure as the one that is shown in the following figure is obtained.



(a) Point-cloud



(b) Wireframe structure

Fig. 3 Basic data of the model

The last step to obtain a model that allows measuring the area and volume of the warehouse implies turning the wireframe structure into a solid model. For this purpose, regions of the different faces of the model are generated by extruding them until a solid body is created. The result is shown in Fig. 4.

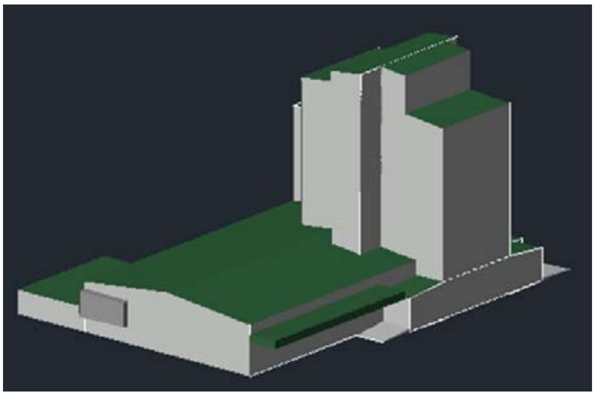


Fig. 4 Solid Model of Agro Cantabria warehouse

B. *Digital Photogrammetry Survey*

Digital photogrammetry methodologies are based on capturing photographic information with digital cameras. In this case, they are mounted on drones that allow the subsequent reconstruction of beams through the conventional photogrammetric process [13]. For the development of a photogrammetric survey, previous planning is required again to define the platform that will be used, and the methodology of work that will be followed [14], in order to optimize resources and get the best results possible.

a) Definition of the Platform of Work

The platform that has been selected for this research is a multirotor device, and more specifically a YUNEEC H520 hexacopter drone (Fig. 5), that was created for professional applications, such as vigilance, construction and the generation of cartography. This kind of platform has been selected due to its average flight autonomy, the robust technology of the sensor, and the possibility that it offers of flying in a stable and precise way even with relatively bad weather conditions. The drone is light, with a weight of 1.63 Kg, and its dimensions are 520 x 455 x 295 mm. Fig. 5 shows the drone that was applied. This platform warrants a reliable determination of the position, as it uses GPS and Glonass and Galileo satellites. In addition to this, it counts with a highly-accurate compass with low interference. The maximum speeds of ascension and landing are 4 m/s and 2.5 m/s, respectively, and it can reach flight heights of 500 m. Its rotation angle is up to 35 degrees, and its speed of rotation is 120 degrees/second.

The next interesting aspect is the selection of a suitable sensor for the envisaged purpose. The main criterion for this choice is the availability of a good accuracy with the lower possible cost. In this sense, the option of a metric camera in the strict sense was rejected, as they have not been adequately contrasted. On the other hand, they are relatively expensive, and this research pursues working with a low-cost device. In order to analyze its possibilities and limitations, the camera that has been used is a quasimetric sensor: the Yuneec E90 camera. It is based in a wide angle image system, high resolution and gimbal stabilization. It is suitable for applications that require high-quality images and videos. The E90 uses a 1-inch sensor with 20 MP, and the most recent high-speed H2 image processing chip.

Fig. 5 Drone applied to capture images

With an accuracy of +/- 0.02°, E90 shots are completely solid, both with low speed or maximum acceleration. The E90 gimbal is able to provide a non-limited 360º rotation of the normal axis. When combined with the foldable landing gear of the H520, this unique feature provides the user a completely-free 360º view of the camera, and the possibility to continuously take panoramic snapshots without diverting the fuselage.

Fig. 6 Yuneec E90 Camera

After choosing the platform, the flight must be planned. The possibility to develop 3 flight is drafted: two automatic nadiral flights at heights of 50 and 65 meters, and a manual flight with a camera tilt of 45º. The results are 169 tilted photographs and 45 nadiral images, with overlaps of 80% and a flight speed of 15 m/s, which implies a total time of flight that does not exceed 10 minutes.

Before managing the information, the control vertices must be acquired, so that they allow making the proper exterior orientation of the model. To this end, a Leica TS02 Topographic Station was applied again. On the basis of the survey points that are applied for the Classical Topographic campaign, six radiations were made, which provided six evenly-distributed control vertices, three on each side of the warehouse.

b) Generation of the Photogrammetric Model

The results obtained with the photogrammetric survey are subsequently processed with the software Agisoft PhotoScan Professional. This software allows processing digital images and, with the combination of digital photogrammetry techniques and computer vision, generating a 3D reconstruction of the environment [15].

The workflow with Agisoft, is the common one with this type of software applications [16], as it can be seen in the main menu/workflow, in which the sequence of activities that must be developed to obtain a 3D model is described. Fig. 7 shows the workflow.

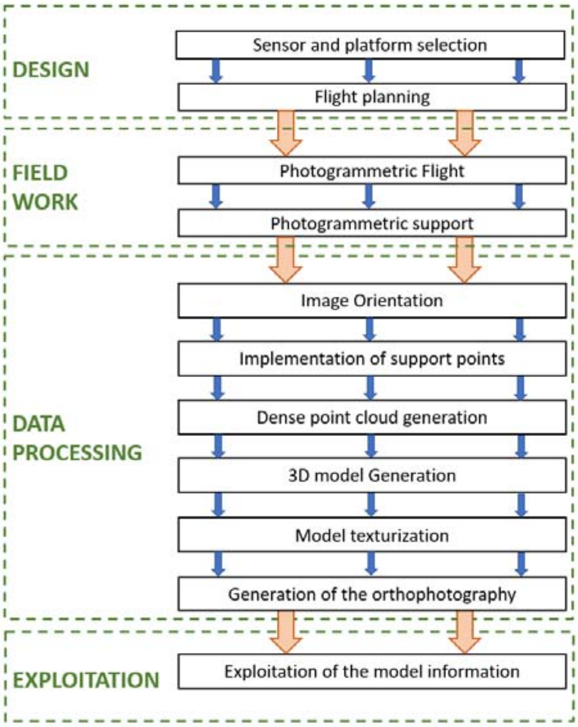


Fig. 7 Workflow to generate the 3D model

Following the workflow, and without any main issue to highlight, the DTM is finally developed, in which the triangles are texturized with the color of the photographs. The obtained model is shown in Figs. 8-10.

III. Results

As the aim of this research is the comparative analysis of a certain object that exists on the terrain, which is modeled with classical and photogrammetric techniques, it must be clear that in both methodologies a perfectly valid DTM has been obtained. Now, it is aimed to compare Distances, Heights, Surfaces and Volumes in them. In order to develop these measurements, the edition tools included in the software used for the development of the classical topographic survey and the photogrammetric campaign are applied. The results obtained in both models are presented below.

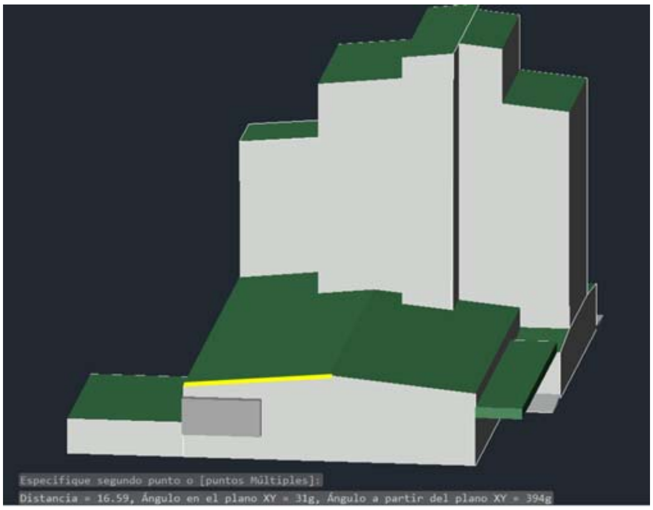
Fig. 8 Main view of the DTM

Fig. 9 Back view of the DTM

Fig. 10 Side view of the DTM

The contrast of distances is developed by measuring perfectly-identified lengths in both models, so as to warrant that the result should be the same in both cases. Figs. 11 and 12 show the determination of the measurement of a distance in both models.

The contrast of area is developed by measuring perfectly identified surfaces in both models, so as to ensure that, in both cases, the result should be the same. Fig. 13 illustrates the determination of the measurement of distances in both models.

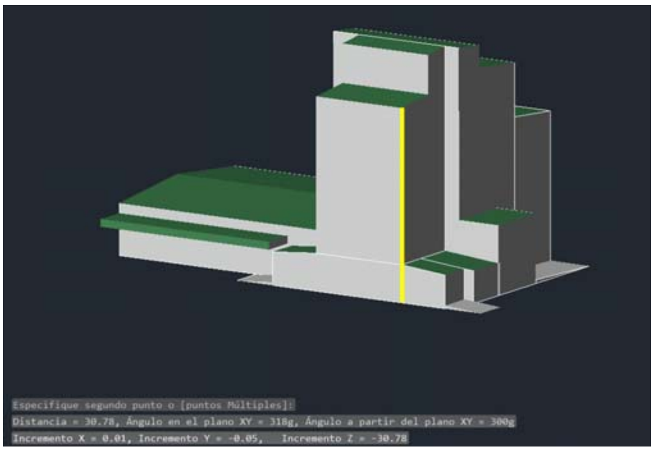


(a) Classical DTM, 16.59 m

(b) Photogrammetry DTM, 16.4 m

Fig. 11 Measurement of distance on the eave

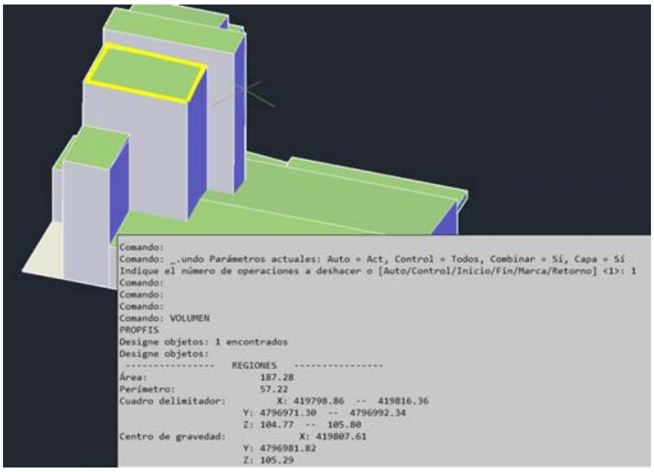
The contrast of volumes is developed by measuring the total volume that is comprised by the whole model in both cases, so as to guarantee that it should be the same. Fig. 14 shows the measurement of volume in both models.



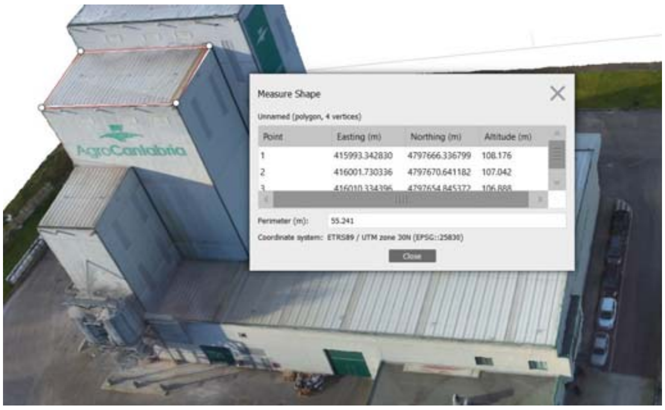
(a) Classical DTM, 30.78 m

(b) Photogrammetry DTM, 30.60 m

Fig. 12 Measurement of vertical distance



(a) Classical DTM, 170.60 m^2

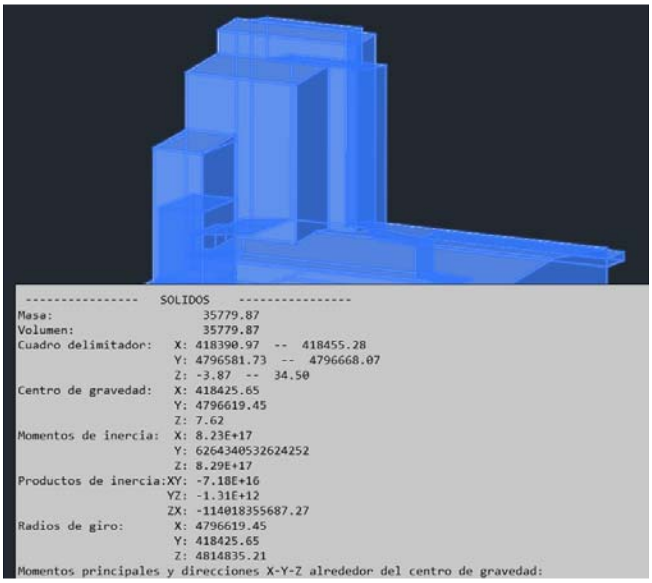


(b) Photogrammetry DTM, 171.15 m^2

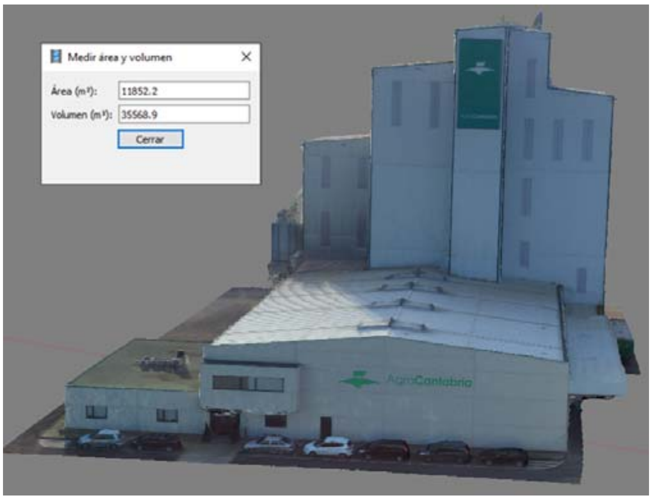
Fig. 13 Measurement of surface on the roof

Table I shows the results of the measurements that were developed with both DTM: the one developed by means of classical techniques, and the one obtained with digital photogrammetry with drone.

Table I illustrates that the differences in the measurement of distances, both horizontal and vertical, range between 20 and 25 cm and the percentages of error in the measurement of surfaces and volumes are 0.32% and 0.59%, respectively.



(a) Classical DTM, 35,779.87 m^3



(b) Photogrammetry DTM, 35,568.90 m^3

Fig. 14 Measurement of the whole warehouse volume

TABLE I
RESULTS OF THE MEASUREMENTS CARRIED OUT IN BOTH MODELS

	Classical DTM	Photogrammetry DTM	Differences	Error %
Distances (m)	16.59	16.40	0.19	0.21
	39.89	39.90	-0.01	
	7.63	7.65	-0.02	
	31.81	31.50	0.31	
	18.47	17.50	0.97	
	13.06	12.30	0.76	
	84.45	85.20	-0.75	
Heights (m)	8.32	8.15	0.17	0.24
	29.50	29.10	0.40	
	30.78	30.60	0.18	
	23.63	23.20	0.43	
	4.00	3.96	0.04	
Surfaces (m^2)	170.60	171.15	-0.55	-0.32
Volume (m^3)	35,779.87	35,568.90	210.97	0.59

IV. DISCUSSION

The results obtained from this research suggest a discussion focused on the test model and the aspects that could be improved. In this sense, it should be noted that:

- This research has been designed with a multirotor UAV device, but it should be reminded that the fixed wing UAV are available, and have a great expansion in the market. Other possible research should be focused on this second type of drones, with full insertion in the field of cartographic applications. Nevertheless, a perfect calibration of the GPS device that allows the subsequent inner orientation of perspective beams is vital.
- Considering the results of the model that has been generated by means of digital photogrammetry, they could probably be improved with a metric camera instead of a quasimetric one, such as the device that has been applied in this research. This factor possibly conditions the obtained results in an excessive way.
- All the support points that allow the external orientation of the model have been determined in the horizontal plane in which the warehouse is located. In a model like this, if support points were given at different heights, the altimetric results might have been better.
- Regarding the photogrammetric software applied for the management of data and the generation of the model by means of photogrammetric techniques, which is one of the most commonly applied alternatives for cartographic purposes nowadays, it can be considered a ‘black box’. The data are introduced in one of its sides and the models are obtained from the other one. A manual processing of the information is difficult. In this sense, software allows managing data with different qualities (low, medium, high and very high). Higher specifications are required as the quality improves. This fact is common in other software programs that might be analyzed in other works of research.
- Although the modelled object has large dimensions and many nooks, the possibility to measure distances, areas and volumes on the model is so excessively reduced. that dissuaded from making a serious statistical study. This justifies that a simple arithmetic average of the differences that were obtained in both models was applied, which is a clearly improvable aspect of this work.

All these issues are improvable factors and precautions that should be considered, and seek helping possible future studies of contrast of DTM developed with drones.

V. CONCLUSIONS

By analyzing the results obtained from the contrast between classic surveying techniques and photogrammetric ones, the following can be concluded:

- Classical surveying techniques allow determining coordinates and the subsequent representation of a point-cloud. The technician must be able to simplify the model, as the number of points that can be acquired with this technique is relatively small. Hence, the technician’s work of discrimination is essential. and its dependence is very high.

- Photogrammetric surveying by means of digital cameras and drones allows acquiring millions of points in a non-discriminant way, and provides the color information of the pictures. Hence, highly-populated point clouds can be obtained, with the possibility to incorporate color and texture without practically any technician's intervention.
- The times of field surveying are high in the case of classical topography surveying (4 days of field-work in for this object), while the time required for the observation of the digital pictures obtained with drones is very low (1 h for this case). On the other hand, the management of data in classical surveying techniques is much faster and easier than data processing in photogrammetric surveying with drone.
- Generally, digital models created from digital photogrammetry with UAV are more detailed and provide more information about the terrain than those obtained with surveying stations, which only include the points that are selected by the surveyor.
- The accuracy in the measurement of distance in both in (x. y) and (z) axis range between 20 and 25 cm. It can be observed that in many cases the difference between them is 1 cm, generally in cases in which the distances are measured on the horizontal plane of reference. It can also be observed that the measurement of heights (z) on both models have bigger differences than horizontal distances.
- The accuracy in the measurement of surfaces has differences of about 0.32% of the measured surface, which justifies the great similarity of the results for measurements generally characterized by being developed on a horizontal plane. Regarding the accuracy in the measurement of volumes, there are differences of about 0.59% of the measured volume, which again justifies the similarity of the results obtained in both models.

Disclaimer

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. Declarations of interest: none.

References

[1] I. Colomina, P. Molina, "Unmanned aerial systems for photogrammetry and remote sensing: A review". ISPRS Journal of Photogrammetry and Remote Sensing. 2014. vol 92. pp79-97.
[2] M. Baeumker, H. Przybilla, "Investigations on the accuracy of the navigation data of unmanned aerial vehicles using the example of the system mikrokopter". International conference on unmanned aerial Vehicle in Geomatics (UAV-G). Book series: international archives of the photogrammetry Remote Sensing and Spatial Information Sciences, 2011, vol. 38-1, pp 113-118.
[3] A.J. Puppala, C.L. Lundberg, "Total system error analysis of UAV-CRP technology for monitoring transportation infrastructure assets". Engineering Geology, 2018, vol 247, pp 104-116.
[4] Guo. Nan, Li. Yongbin, "The Accuracy of Low-Altitude Photogrammetry of Drones". International Journal of Pattern Recognition and Artificial Intelligence, 2020, vol 34, Issue 8.
[5] Sadeq. Haval A, "Accuracy assessment using different UAV image overlaps". Journal of unmanned vehicle systems, 2019, vol 7, Issue 3, pp 175-193.
[6] A. Saiful, R. Jesper, N. Jon, et al, "Manual geo-rectification to improve the spatial accuracy of ortho-mosaics based on images from consumer-grade unmanned aerial vehicles (UAVs)". Precision agriculture, 2019, vol. 20, Issue 6, pp 1199-1210.
[7] J. Marion, P. Sophie, L. B. Rejanne, et al, "Assessing the Accuracy of High Resolution Digital Surface Models Computed by PhotoScan and MicMac in Sub-Optimal Survey Conditions". Remote Sensing, 2016, vol. 8, issue 6.
[8] L. Jaeone, "Analysis of 3D Positioning Accuracy of Vectorization Using UAV-Photogrammetry". Survey geodesy, fhotogrammetry and cartography, 2019, vol. 37, issue 6, pp 525-533.
[9] Battulwar, R., Winkelmaier, G., Valencia, J., Naghadehi, M. Z., Peik, B., Abbasi, B., Parvin, B., & Sattarvand, J. (2020). A practical methodology for generating high-resolution 3D models of open-pit slopes using UAVs: Flight path planning and optimization. Remote Sensing, 12(14). https://doi.org/10.3390/rs12142283
[10] El-Din Fawzy, H. (2019). 3D laser scanning and close-range photogrammetry for buildings documentation: A hybrid technique towards a better accuracy. Alexandria Engineering Journal, 58(4), 1191–1204. https://doi.org/10.1016/j.aej.2019.10.003
[11] Carrera-Hernández, J. J., Levresse, G., & Lacan, P. (2020). Is UAV-SfM surveying ready to replace traditional surveying techniques? International Journal of Remote Sensing, 41(12), 4818–4835. https://doi.org/10.1080/01431161.2020.1727049
[12] Mill, T., Alt, A., & Liias, R. (2013). Combined 3D building surveying techniques-Terrestrial laser scanning (TLS) and total station surveying for BIM data management purposes. Journal of Civil Engineering and Management, 19(SUPPL.1), 23–32. https://doi.org/10.3846/13923730.2013.795187
[13] Pepe, M., & Costantino, D. (2021). Uav photogrammetry and 3d modelling of complex architecture for maintenance purposes: The case study of the masonry bridge on the sele river, italy. Periodica Polytechnica Civil Engineering, 65(1), 191–203. https://doi.org/10.3311/PPci.16398
[14] De Luis Ruiz, J. M. de, Sedano Cibrián, J., Pereda García, R., Pérez Álvarez, R., & Malagón Picón, B. (2021). Optimization of Photogrammetric Flights with UAVs for the Metric Virtualization of Archaeological Sites. Application to Juliobriga (Cantabria, Spain). Applied Sciences, 11(3), 1204. https://doi.org/10.3390/app11031204
[15] N., Cramer, M., & Rothermel, M. (2013). Quality of 3D Point Clouds from Highly Overlapping Uav Imagery. ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XL-1/W2(September), 183–188. https://doi.org/10.5194/isprsarchives-xl-1-w2-183-2013
[16] Rakha, T., & Gorodetsky, A. (2018). Review of Unmanned Aerial System (UAS) applications in the built environment: Towards automated building inspection procedures using drones. Automation in Construction, 93(September), 252–264. https://doi.org/10.1016/j.autcon.2018.05.002