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Fotogrametría aplicada al levantamiento gráfico en proyectos de rehabilitación: estudio de caso de una vivienda unifamiliar.

Photogrammetry applied to graphic survey in rehabilitation projects: case study of a detached house.

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Resumen-- **Esta comunicación analiza el trabajo realizado para el levantamiento gráfico de un caso de estudio durante su proceso de rehabilitación. Para ello se ha utilizado la técnica de la fotogrametría junto con un sistema RPAS para la adquisición de fotografías del inmueble. Como resultado se ha obtenido una nube de puntos que permite realizar la caracterización geométrica del caso de estudio. El uso de ambas técnicas ha demostrado ser una combinación muy útil en el campo de la arquitectura y los procesos de rehabilitación gracias a la posibilidad que ofrece para la captura masiva de datos y su posterior uso para el desarrollo del modelo arquitectónico. Este análisis ha permitido comprobar las ventajas y desventajas de la metodología seguida en el estudio frente a los métodos convencionales de levantamiento arquitectónico.**

Palabras clave— Rehabilitación de edificios; Fotografía geoetiquetada; Levantamiento gráfico; Fotogrametría; RPAS.

Abstract— **This communication analyzes the work carried out for the graphic survey of a case study during its rehabilitation process. For this, the photogrammetry technique has been used together with an RPAS system for the acquisition of photographs of the property. As a result, a point cloud has been obtained that allows the geometric characterization of the analyzed case study. The use of both techniques has proven to be a very useful combination in the field of architecture and rehabilitation processes thanks to the possibility it offers for massive data capture and its subsequent use for the development of the architectural model. This analysis has allowed verifying the advantages and disadvantages of the methodology followed in the study compared to conventional methods of architectural survey.**

Index Terms— Building retrofit; Geotagged photograph; Graphic survey; Photogrammetry; RPAS.

I. Introduction

I The AEC sector is currently facing an important challenge in order to optimise construction processes and in this sense, innovative technologies allow us to support this transformation process. In this field, there are multiple solutions that can be applied in the three phases of the value chain of the sector: design, construction and O&M. In the area of architectural surveys, tools such as 3D laser scanners, RPAS and photogrammetry [1-6] are being applied with great success. (Xiong et al., 2013; Barrera Vera et al., 2017; Pérez Martínez et al., 2019; León et al., 2020; Jiang et al., 2020; Pérez Zapata et al., 23020) These technologies make it possible to obtain high quality point clouds of buildings with millimetre accuracy, a goal that is practically unattainable with traditional surveying techniques. Furthermore, these point clouds offer the advantage of being subsequently integrated into BIM software for high-precision modelling and the corresponding derived advantages.

One of the clear advantages of photogrammetry for point cloud generation is its cost, making it the most affordable digitising technique. The quality of the results depends directly on the level of equipment used; however, the photogrammetric technique only requires a camera and software.

Two of the most widespread software packages are Photomodeler and Agisoft Metashape (formerly Photoscan). Multiple studies analyse the advantages of both software being mainly used for cartographic works or for heritage documentation (Kingsland,, 2020). On the other hand, given the current needs in the digital model generation sector, there are more and more options available such as Pix4D, Bentley Context Capture or RealityCapture. In this sense, there are even open-source alternatives such as VisualSfm, MicMac, GRAPHOS, Bundler, among others (González Aguilera et al., 2018; López Medina et al., 2019).

Another advantage offered by the photogrammetric technique is the ability to work with georeferenced data. By means of control points it is possible to generate highly accurate georeferenced models for application in the AEC sector. On the other hand, it is worth remembering the possibilities offered by photographic cameras to incorporate georeferenced information from the EXIF image file format that allows the incorporation of the geographical coordinates of the position from which the photograph has been taken, also known as geotagging, in the metadata of the images. Furthermore, taking advantage of the benefits offered by RPAS for the aerial capture of geo-referenced photographs, it is possible to capture large areas for surface analysis. In this way, Digital Terrain Models (DTM) could be generated relatively easily, and the data subsequently analysed with Geographic Information Systems (GIS).

The aim of this paper is to carry out the graphic survey process supported by the photogrammetry technique and to apply it to a rehabilitation case study. The communication presents the methods followed, as well as the workflow required for this type of work supported by RPAS systems for the acquisition of photographs.

II. Methodology

The case study analysed is a single-family dwelling located in the municipality of Donostia-San Sebastián, specifically on Mount Igeldo in the western part of the city, Figure 1. The dwelling has a total of 167 m2, divided into a main floor and a semi-basement. The building has been chosen as a case study on the one hand because it has been refurbished (Figure 2) and the project team required a point cloud to have an accurate model to work with. On the other hand, the building is located on a plot of land with a sloping surface that will allow the generation of a topographic model with appreciable differences in elevation.

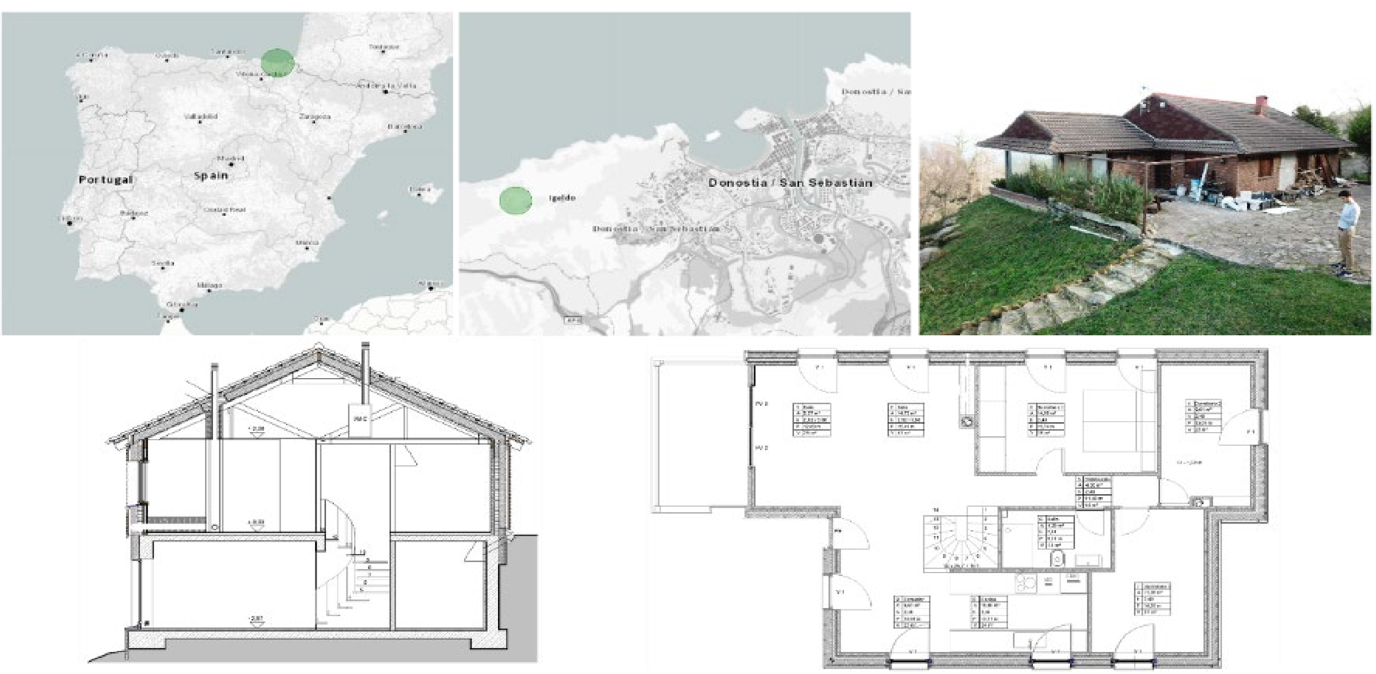

Fig. 1. Case study.

Fig. 2. Original and rehabilitated state of the case study (Source: Own authorship)..

Fig. 3. Workflow used in photogrammetric software.

The RPAS Mavic Pro Platinum from DJI was used to capture the images. The equipment incorporates a 1/2.3" sensor (CMOS) of 12.35 effective Mpx and a 78.8° 26mm FOV lens (35mm equivalent) with f/2.2 aperture. It has a dual-band satellite positioning system (GPS and GLONASS) and the following stationary flight accuracy ranges, vertical ±0.1 m (with visual positioning) ±0.5 m (with GPS positioning) and horizontal ±0.3 m (with visual positioning) ±1.5 m (with GPS positioning). The flight autonomy is approximately 30 minutes.

The previously mentioned Agisoft Metashape photogrammetric software was used to process the images. As for the workflow followed with the software, Figure 3 shows the main steps followed to obtain the results shown in this research. Finally, regarding the equipment used, a PC with Windows 10 operating system was used, with Intel Core i9-9900K CPU, NVIDIA Quadro P4000 GPU with 8Gb of VRAM memory and 64 Gb of RAM memory.

III. Results

A. *Results discussion*

Regarding the process of the graphic survey, Figure 4 reflects the general steps carried out. Initially, oblique and nadir aerial images were captured around the case study and were taken in manual mode in order to have greater control during the flight. Once the photographs were acquired, they were imported into the photogrammetry software in order to start with the cabinet work and follow the steps previously presented in Figure 3.

The first step was to generate the step point cloud required to

Fig. 4. Graphic survey process of the case study. (own elaboration)

Fig. 5. Dense point cloud models: a) Medium quality b) High quality (Source: Own elaboration)..

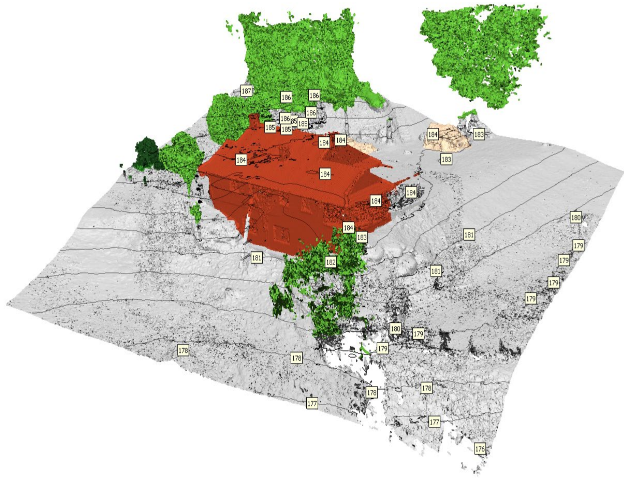

Fig. 6. Graphic survey process of the case study. (own elaboration)

TABLA I
DENSE POINT CLOUD MODELS.

Calidad del modelo de nube de puntos densa	Tiempo de procesamiento	Número de puntos
Media	1 h 46 min	7,08 M
Alta	9 h 18 min	31, 25 M

obtain the final dense point clouds. The time required to obtain the first step point cloud was 3 minutes for the search of the photograph pairings and an additional minute for the orientation of the photographs, resulting in a cloud of 258,875 points. From this first cloud, two dense point clouds were subsequently generated, with medium and high quality respectively, in order to show the ratio of computational time required versus the results obtained. Figure 5 shows that the difference between the two clouds is only noticeable when the view is brought closer to the model. This result is due to the difference in the number of end points obtained in both cases, Table 1. As can be seen, the volume of the high-quality point cloud is more than four times greater than the medium quality one, with a corresponding increase in the processing time required to obtain it.

Fig. 8. Dense point cloud models: a) Medium quality b) High quality (Source: Own elaboration)..

During the second step, once the point clouds had been generated, the point information was processed in order to generate topographic documentation of the analysed area. However, before this, the point cloud requires a general identification of the type of data it represents. The main reason for this is that it is possible to use different types of models for the representation of topography. Generally, when describing any type of raster elevation surface, it is referred to as a Digital Elevation Model (DEM). However, if the model represents ground elevations together with heights of structures such as buildings and trees, it may be referred to as a Digital Surface Model (DSM). Finally, if the elevations represent the elevation of the terrain, the model is called a digital terrain model (DTM).

As mentioned above, the first step was to make the main classification of the types of points in the model, Figure 6. For this purpose, a classification was made according to the following classes: land (grey), building (red), high vegetation (light green), low vegetation (dark green) and other objects (gold). Through this classification, it has been possible to obtain both the contour lines identified in Figure 6 itself and the DSM and DTM of the case study, Figure 7. Finally, Figure 8 represents the orthomosaic of the case study in which the

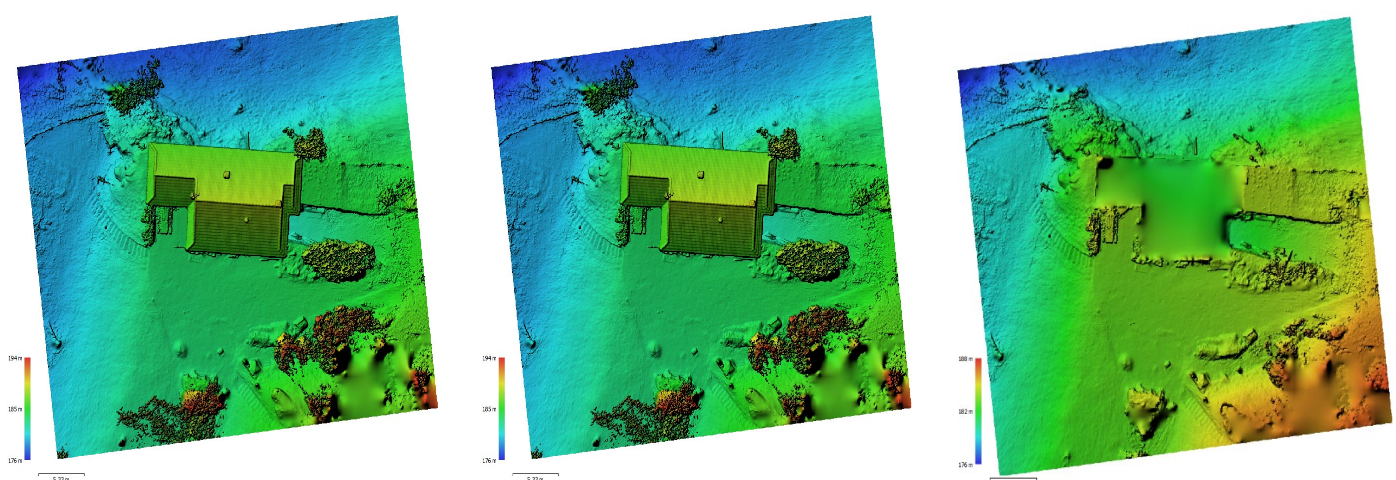

Fig. 7. Digital Surface Model and Digital Terrain Model of the case study (Source: Own elaboration).

perspective of each individual image generated by the tilt of the camera is corrected in order to form a rectified general image of the whole where measurements can be taken.

IV. Conclusions

This work has analysed the process of graphical survey of architectural models based on a case study and the technique of photogrammetry. Specifically, it has been applied to a single-family house in order to facilitate the process of capturing geometric data prior to the renovation phase. By means of the work developed, it has been possible to generate a digital model based on a point cloud with a high definition. The differences obtained in the processing times and the corresponding degree of definition of the points between the medium and high-quality models have also been shown.

On the other hand, the photographs taken by RPAS incorporated information on the position from which they were obtained and therefore allowed a georeferenced model to be generated. Among the results obtained, it has also been possible to obtain both the Digital Surface Model (DSM) and the Digital Terrain Model (DTM), which allow the plot to be defined and topographical studies to be carried out.

It should be noted that the purpose of the present study was to show the graphic survey of the case study in order to demonstrate the workflows and the advantages of using the technologies employed. Future research could focus on the exhaustive analysis of the generated models and compare them with the results obtained using high-precision Real-Time Kinematic (RTK) RPAS models incorporating a GNSS ground station as an example.

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