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Digital preservation of the Jesuitas Church in Valencia (Spain) using 3D laser scanning

J Moreno-Puchalt[1], A Almerich-Chulia[1] and X Laumain[2]

[1] Universitat Politècnica de València, School of Architecture, Department of Continuum Mechanics and Theory of Structures, Camino de Vera s/n, 46022 Valencia, España
[2] ARAE Patrimonio y Restauración, S.L.P.

E-mail: jemopuc@mes.upv.es; analchu@mes.upv.es; xavier@arae.es

Abstract. The urgent need to improve the quality in the refurbishment of historical buildings has led to the adoption of many innovative technologies. 3D laser scanning is a non-destructive technique used in the study of architectural heritage. It consists of producing millions of accurate 3D points with a very high point density in a short time. To get the complete 3D model, multiple shots must be taken from different directions that provide data from all sides of the building. These scans are integrated into a common reference system so that through a process of aligning the information obtained in all the stations, a complete model is achieved in a single file. This model faithfully reproduces the current volume of the temple, including its deformations and collapses, and provides very precise information from which to make its geometric survey. The refurbishment project of the Jesuitas Church in Valencia (Spain) has been realized thanks to the help of 3D laser scanning carried out three times during the years 2018, 2019 and 2020. The results obtained have not only served to make a very precise graphic survey but have also been applied in the necessary structural calculation.

1. Introduction

Today and increasingly, we have the urgent need to improve the quality in the refurbishment of traditional buildings. The continuous advance in the field of electronics allows us to access a wide range of solutions and tools that were once unimaginable. This reason has led to the adoption of many innovative technologies, specifically 3D laser scanning. The 3D laser scanner is a clear example of innovation and advancement, being a powerful and incomparable measurement tool that arises from the field of topography and it is more frequently present in the building, refurbishment, and architectural heritage sector [1]. Its operation consists of generating a point cloud that reproduces the building under study and its immediate surroundings. To get the complete model of the building, multiple shots must be taken from different directions that provide data from all sides of the building, generating multiple files containing millions of accurate 3D points with a very high point density in a short time. These scans are integrated into a common reference system so that a complete model is achieved in a single file through a process of aligning the information obtained in all the stations. This model faithfully reproduces the current volume of the building, including its deformations, and provides very precise information from which to make its geometric survey.

As a result of the scan, a point cloud is obtained that represents a copy of reality at a 1:1 scale from which the most diverse information about the generated virtual model can be obtained, such as high-resolution orthophotos, measurements in true magnitude, integration of the point cloud in BIM software, virtual tour of the model or even 3D printing [2].

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It offers multiple advantages in measurement or data collection. These include precision, quality and speed, in addition to its versatility, simplicity and scope. It is a highly efficient tool as it reduces fieldwork time.

The building under study is the Jesuitas Church located in Valencia (Spain). The church was consecrated on October 12, 1887. It has a Neobyzantine style with some Neoromanesque touches. The church is made up of three naves with seven bays and an altar (figure 1). It also has a two-sided roof cover and a barrel vault with lunettes [3]. Although the state of conservation is relatively good, the building has numerous pathologies that have affected the whole of the Church. To carry out the pertinent refurbishment project, it is necessary to previously have an exhaustive graphic survey. Therefore a 3D laser scan is performed [4].

Picture from the altar

Side nave

Figure 1. State of the church during 3D laser scanning in 2018.

2. Methodology of laser scanning
The scanning process can be divided into three stages: scan plan, data collection and data processing.

2.1. Scan plan
A scan plan is a set of information that describes the scope and approach that will be taken to capture the data at the site. A scan plan should be made after setting the project goals.

Many times a scan plan begins with a detailed analysis of what elements need to be captured. In the case of scanning a building for the first time, you will want to capture the position of all the elements. In the case of continuing with a work started previously, it is possible to set specific work areas on which more information needs to be collected.

Identifying the exact target of the items to be analyzed helps the field team to prioritize their efforts and reduce the time spent capturing unnecessary data. With a clear goal in mind, a document can be created that identifies the optimal location for each scanning station.

In the case of scanning both the interior and exterior of the building, it is important to study the optimal location of each station so that the subsequent joining of the point clouds is carried out correctly.

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2.2. Data collection

Scan parameters can be changed from settings at any time during scanning. The main parameters include creating a scanning project, selecting a scan profile indoor and outdoor and setting resolution and quality.

It must be taken into account for the location of the reference points that mathematically three common references are needed between two consecutive scans. However, a higher number of common references per scan will improve the registration results, making it easier and less likely to be errors.

Figure 2. Location of the spheres in the lateral nave.

The scanner used is Faro Laser Scanner Focus 150. Scene, which is the software that Faro technology uses, allows the union of point clouds by points, by planes or by spheres [5]. The spheres used as markers should not be positioned symmetrically with the building. They must form a polygon around the scanner and have varying distances to it. The ideal thing is to place them at different heights, distances and planes as shown in figure 2 and figure 3.

Figure 3. Faro Laser Scanner Focus 150 in the central nave.

The number of stations depends on the size and shape of the building. The scanning time depends on the number of stations, the quality and resolution, the complexity of the scanned building…

2.3. Data processing

The immediate result obtained from the laser scan is a series of point clouds. Each point is represented by coordinates (x,y,z). All point clouds are recorded together in a common coordinate system, resulting in a single point cloud.

Once the complete point cloud is obtained, unnecessary information is eliminated such as people, equipment, surrounding buildings, trees or noise, and then the color is applied (in the case of having scanned in color and not in black and white). Once all the previous steps have been carried out, the project documentation can be prepared by starting the preparation of plans [6].

3. Case study: The Jesuitas Church in Valencia (Spain)

The Jesuitas Church in Valencia requires a comprehensive restoration intervention. This action will range from structural aspects, through decorative aspects, to the adaptation of facilities. Due to this, it is necessary to carry out a graphic survey as exact as possible [7].

A first scan of the church was carried out indoors in 2018. The main objective was to draw the interior of the church in an accurate way. It was also important to check the layout of the vaults. Regarding scan parameters, in our case, we chose indoor to 10 meters, resolution 1/5 and quality 4x which took us an approximate scan time of 8 minutes. Figure 4 shows the indoor stations.

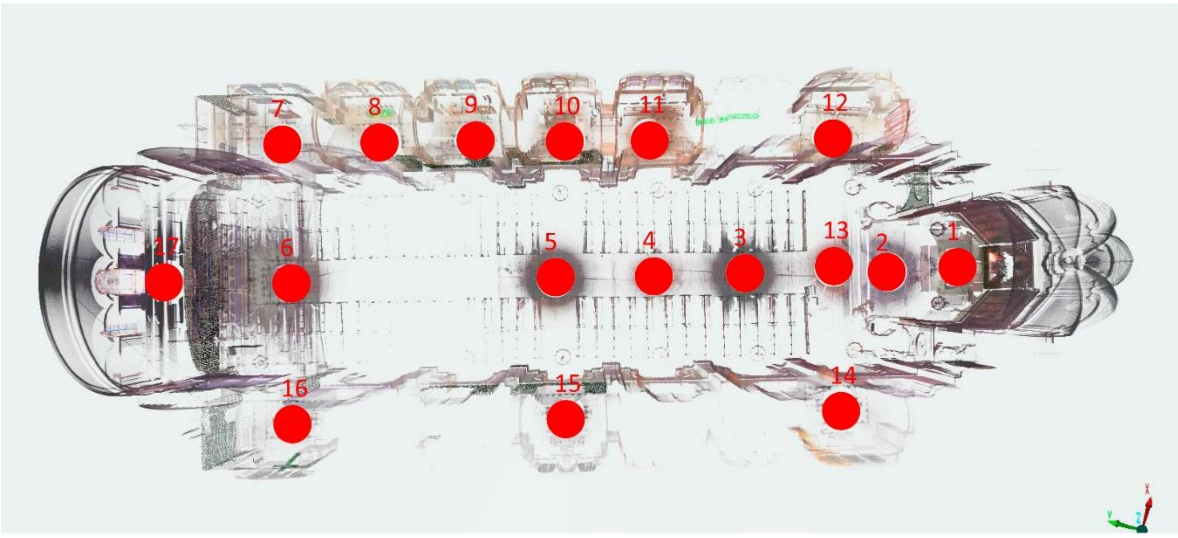

Figure 4. Seventeen positions of the laser scanner.

We decided that the first position of the scanner was at the altar (positions 1 and 2). We continued through the central nave towards the foot of the church (positions 3 to 6), then the right and left sides aisles (positions 7 to 16) and finally went up to the choir (position 17). The total scan time was six hours. This time consisted of installing the scanner, deployment of reference spheres and also changes in positions of the scanner and markers. The positions of the reference points were often different because we had available just five pieces of reference sphere. Due to this, in the union of point clouds, we had to also use planes and not only spheres. In this case, the union defined by planes also provides us with great precision since the marble cladding of the church bases defined perfect planes.

It is important to keep some considerations into account. Very dark surfaces absorb most of the visible spectrum and the reflected signal will be very weak. In contrast, very light surfaces are highly reflective and produce strong reflections. However, if the reflectivity of the object is too high, the laser ray is fully reflected in the direction of the reflection and will either hit another surface or be scattered. This is why shiny surfaces like gold are not easy to register. It can be scanned through the glass, but not with high precision as the glass will refract the ray and give inaccurate data.

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We must do the office work once the fieldwork is finished. This work consists of the union of point clouds using Scene by FARO [5]. Each point cloud is joined with the next one by selecting common references that can be spheres, planes or points, as we can observe in figure 5 and figure 6.

Figure 5. Joining stations 5 and 6.

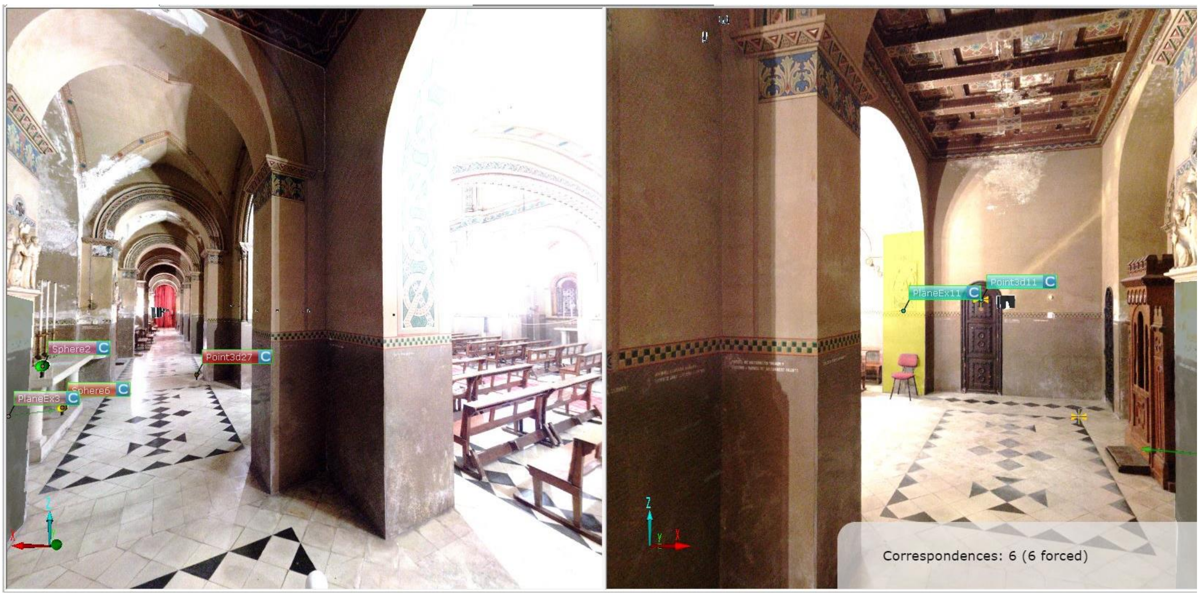

Figure 6. Interconnection between central nave and lateral nave.

This program offers simple measurements, coloring the point clouds, deleting unnecessary points and export the complete point cloud to various formats. Figure 7 shows the finished work.. We use the RCP format to import the point cloud into a CAD program. In this case, the program we work with is Autocad.

This software allows us to make countless sections in the complete point cloud and draw the 2D plans that interest us in generating them in a short time. Façade, floor plans, sections and details can be elaborated simply by making cuts to the complete cloud and drawing on top of them using them as a template (figure 8).

Figure 7. Complete cloud of the interior of the church.

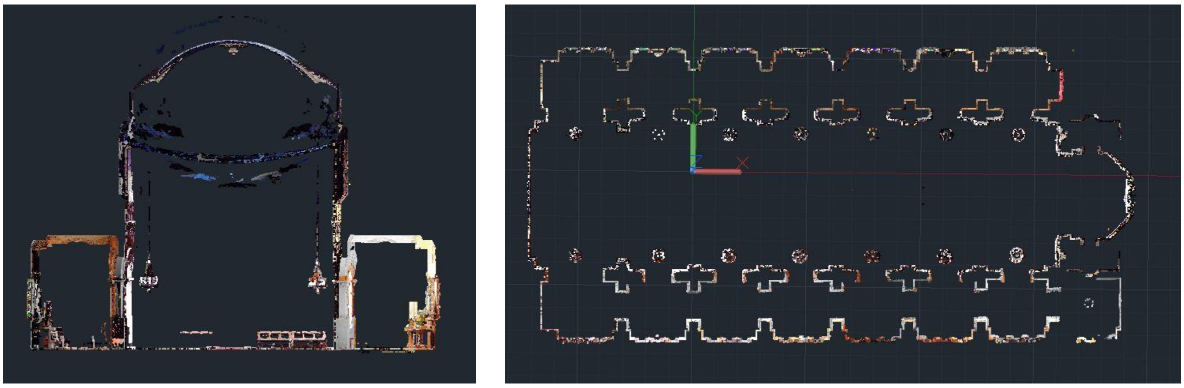

Figure 8. Preparation of sections and floor plan.

4. Conclusion

For the drafting of the project that was presented to obtain the appropriate licenses, this 3D scan of the building has been carried out in order to obtain a real-size and reliable image to refine the intervention in it and adhere to the ideal works according to the requirements.

This paper shows 3D laser technology as a state-of-the-art tool for drawing with great precision plans of traditional buildings. It has been described step by step how to prepare the graphic documentation of Jesuitas Church in Valencia. There is no doubt that the 3D laser scanner is a very effective tool to carry out graphic surveys of the current state of historic buildings.

5. References

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