


Challenges to achieve a digital twin in historical monuments: The case of the church of San Antonio Abad

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Abstract

Given the importance of the conservation of cultural property and the use of the digital twin as a tool for the representation of its life cycle and enhancement, we will carry out a digitisation project approach on the Church of San Antonio Abad and its protective environment, located in the city of Valencia (Spain) and currently considered an Asset of Local Relevance.

A theoretical approach is made to how the digital twin could be created, taking into account the various existing techniques, namely 3D scanning, photogrammetry, and BIM methodology, to achieve the complete digitisation of the monument. This first approach allows us to understand the evasion of this property and its challenges so that the digital twin can be realised in the future.

Keywords: digital twin, cultural heritage, monument, conservation.

1. Introduction

Digitisation captures reality by converting physical source material into digital source material (Rouse, 2024), which has tags with several levels of information called metadata.

This metadata is structured, and the information is organised and associated with the digital product for multiple purposes. (Montero, Fernandez, & Rodriguez, 2003)

Metadata should be recorded according to standards so that the same principles apply universally, regardless of the object, collection or cultural institution.

The rationality of the efforts to digitally represent that material fraction implies an inherent complexity. This is due to the need to select and manage data sets and consider the levels of information accessible in the final digitised product. The concept of digital twins is the starting point for interacting with the digitised heritage. The digital twin should be understood as the origin and not the end of a digitising project, as this is the starting point for interacting with the heritage asset. (Castillejo, 2022)

2. Objective

The objective of the research is to perform a theoretical approach that allows us to address the realisation of a digital twin within the singularities of the heritage building called Church of San Antonio Abad, located on Sagunto Street, numbers 188 and 186 (Figure 1-2) to achieve as a first step of a digitising project; a digital twin that I can serve later for other purposes.

It is wanted to put in value good of local relevance, hidden and not visitable of the city of Valencia, directed to the citizens and the members and owners of this building, as well as to future works of investigation and works of rehabilitation and restoration of the monument.



Figure 1: Location of the property and its protected environment. Source: Blanco Estévez (2022).



Figure 2: Location of the property and its protected environment. Source: Blanco Estévez (2022).

3. Methods and procedure

To carry out the objective of the research, it is necessary to know its history from its origins to the present, identifying the gaps in knowledge and establishing a solid base through a documentary, descriptive and explanatory research that allows us to know the monument from a global vision.

The most relevant procedures/techniques are defined for each part of the described property to verify the most effective way to digitise it, given its amplitude and the location of the different relevant elements.

3.1. History of the Church of San Antonio Abad

In 1095, the order of the Antonians was born, attributed to Gaston Dauphine, a French nobleman whose son contracted the disease known as St. Anton's fire, which was caused by ergot. In 1228, Pope Honorius III confirmed the Hospitaller Order. The order would adopt the Blue Tau and the brown or black habit as its hallmark. (Burns, 1982; Rubio Vela, 1984) (Figure 3)



Figure 3: Picture *Las Tentaciones de San Antonio* from El Bosco. Source: Prado Museum, Spain.

The Antonians arrived in the city through the diocese of Tortosa, Barcelona. The Antonians bought land in the Orriols district, making their "foundation" in 1404 and later building the hospital with diaphragm arches and a Mudejar roof between 1415 and 1440, two of which are still preserved today (Blanco Gómez, 2015). (Figure 4)



Figure 4: Detail of the roof at present. Source: Blanco Estévez (2022).

With the construction of the General Hospital of Valencia in 1512, the convent lost its hospital status. It began its transformation into an alms order (obtained by papal bull by John XXII in 1287-1297). The hospital was transformed into a church during the 16th (communion chapel) and 17th centuries (new facade), culminating with the great neoclassical reform carried out by the friar architect Fray Francisco de Santa Barbara, which lasted until 1768, a date engraved on the exterior façade of the convent. During this work, all the Gothic ceilings, arches and other elements of the fifteenth century will be masked, building around them the new building, expanding it to generate a Latin cross church with a dome in the transept and a large adjacent cloister. The bell tower was enlarged to its present size, which can be seen today (Blanco Estévez, 2022) (Figures 5-7).



Figure 5: Cloister Aerial view source: Blanco Estévez (2022).



Figure 6: Corner of the outer facade of the cloister. Source: Blanco Estévez (2022).



Figure 7: Interior of the church at present. Source: Blanco Estévez (2022).

At the end of the 18th century, in 1787, Pope Pius VI suppressed the order, and the Antonians were forced to leave, leaving the church empty until the arrival of the Dominican Order of St. Onofre in 1804. They transformed the communion chapel into a chapel consecrated to the Virgin of the Rosary. They abandoned the convent in 1835 after the disentailment of Mendizabal, the cloister remaining in the State and passing into the hands of individuals and the church was claimed by the Archbishopric and ended up being the parish of Orriols in 1845 (current neighbourhood of the city of Valencia) (Ballester Olmos, 1984; Eslava Castillo, 1976).

In 1872, they bought the conventual part from private individuals to the Order of the Canonessas de San Cristóbal, cloistered nuns who reformed the convent (Ortí, 1899). It would be until 1899 that they sold the convent to the Order of the Salesian Fathers, which is the order that still owns the building today, celebrating 2024, 125 years after its arrival the building. The Salesians will build their school around this property, expanding the adjoining buildings to become the large block that it is today (Díaz Rivas, 1990) (Figure 8).



Figure 8: Surrounding area of the current Salesians plot. Source: Google Maps (2022).

3.2. Digital Twin: Tools

Having seen the history of the building, we can determine that at the level of digitising, this building has two well-differentiated parts that give value to the monumental set. On the one hand, the Mudejar roof of the XV century, and on the other hand, the neoclassical church completed in 1768, which hides the Gothic remains mentioned.

The rest of the adjacent buildings that exist at present will be observed during the realisation of the twin as they interfere with the building, and it will be perceived if it is necessary or not digitisation. Also, it can be estimated if this is necessary, but it will not be known with certainty until the empirical part is carried out.

With the above seen, the different items to carry out the digital twin project are raised, along with the information we already have about the property.

3.2.1. Photographic survey

Digital photogrammetry has had a major impact on the digital era by enabling the creation of accurate and detailed three-dimensional models from photographs. Modelling opens new possibilities in architecture, engineering and cultural heritage conservation fields. In addition, photogrammetry is a valuable tool in archaeology and historic building preservation. This technique uses photographs to measure and create accurate three-dimensional (3D) models of objects and structures, allowing researchers and conservation experts to efficiently capture and document cultural heritage in detail. In short, digital photogrammetry is a technological discipline that revolutionises the way we document, study and disseminate cultural heritage by unlocking a range of possibilities for the documentation and conservation of monuments, historic buildings, archaeological pieces and sites (Marqués & Colom Mendoza, 2022; Patrimonio Global, 2023).

In our building, photogrammetry of the Mudejar roof is considered feasible, although it would not be easy to perform.

To begin with, only two bays are preserved, each in a different place, so we would have to make two different surveys. Then, the roof of each bay would have to be divided into several parts to fit in its entirety. That is to say, we would have to treat each roof by the number of sections considered necessary, considering that between the vault and the roof, there is no room for a standing person, and the light is scarce. Therefore, to get a good shot, we would have to create an atmosphere with enough light to create different clouds of dots and then join them together. You can use Agisoft Metashape to do this (Figure 9).



Figure 9: Remaining space in the first bay. Source: Blanco Estévez (2022).

3.2.2. Scanning technologies

The 3D scanner provides depth information, the geometry of the scanned object, and, usually, texture or photographic information. It is known that a camera, for example, also captures information about the environment around us based on the surface without providing in-depth information. The 3D scanner digitises objects to have them in virtual form and access more information (Polo et al., 2019).

Scanning an object or scene generates a point cloud, an unorganised set of points in three dimensions. The scan is a massive capture of information, which must be cleaned and processed. This processing includes different operations such as cleaning, merging different scans, filtering, generating a triangle mesh, texturing, etc. It is, therefore, a complex process and depending on the number of scanners, it is expensive.

We currently have a 2D survey carried out using a flexometer, tape, and laser. Therefore, it would be interesting to perform, at least of the church's interior, a scan that improves the accuracy of the data available so far.

It is not considered, in principle, to treat the roof with 3D scanning because of the complexity of the placement of the equipment. Still, it is possible to consider combining both techniques, photogrammetry and 3D scanner.

3.2.3. Data management

The use of the Building Information Modeling methodology in the field of cultural heritage has generated its own disciplinary field under the name Heritage BIM (hereinafter HBIM). The use of BIM methodology is not an abstraction. It is a way of doing things (Rios, 2022).

At this point, the property is at a level of maturity, according to the Bew-Richards Level 0 model, which means that it has been worked on in 2 dimensions with CAD (Computer Aided Design) software. If we go to ISO 196520, we would be at stage 1, where 2D CAD drawings and information models are combined.

Therefore, it makes sense that with the help of the scans to be made and the point clouds obtained by photogrammetry, H-BIM is applied as the main tool for our digital twin to complete the "matryoshka" that is this building and to manage the level of information that a building of these characteristics has (Figure 10).

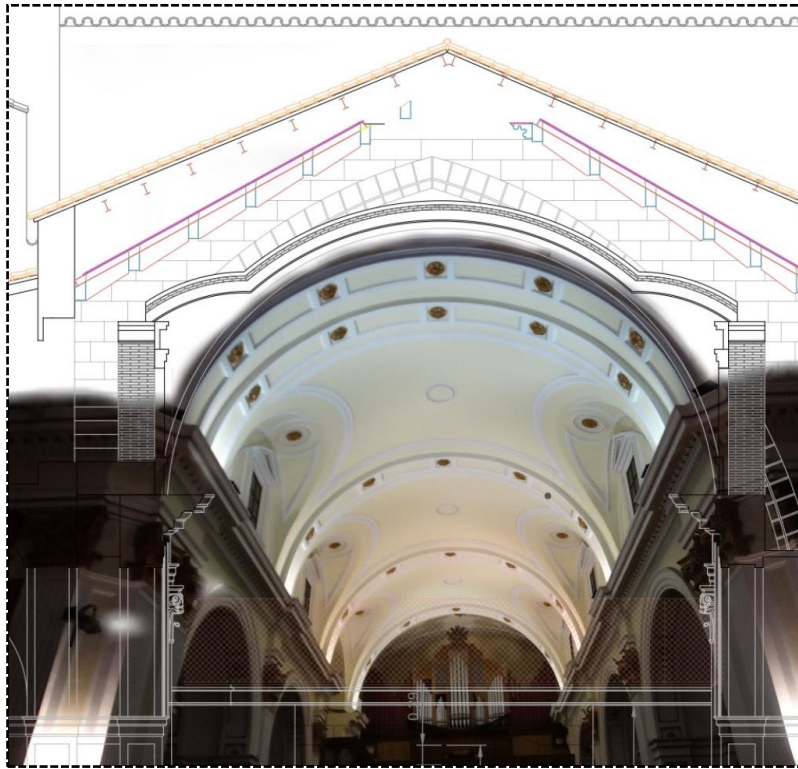


Figure 10: Photograph of the interior of the church inserted inside a section by means of Procreate.
Source: Blanco Estévez (2022).

4. Results

As observed in the four main works that have been carried out on this building, namely:

- The doctoral thesis “Resultados de la investigación directa en la iglesia de San Antonio Abad”. Domingo Alfonso Eslava Castillo in 1976
- The doctoral thesis “Análisis arquitectónico y constructivo de la techumbre en madera policromada de la Iglesia de San Antonio Abad, como pervivencia de la arquitectura tardogótica mediterránea de la Valencia del siglo XV.” Pedro Rafael Blanco Gómez in 2015
- The final Master's thesis “Estudio constructivo del convento de los Antonianos en la Valencia extramuros. Desde su fundación hasta las grandes reformas del siglo XVIII y su posterior adaptación a colegio salesiano” Paula Blanco Estévez in 2022.
- The book “La techumbre tardogótica de la madera policromada oculta en la iglesia parroquial de San Antonio Abad (Valencia) from Pedro Rafael Blanco Gómez en 2023.

This heritage asset is important within the city of Valencia and specifically as part of the great forgotten Valencia outside the city walls. This makes it necessary to undertake a digitisation project of this magnitude to enhance its value, disseminate it and be able to intervene and preserve it.

Below are some of the 2D CAD drawings and volumes previously made that are the basis for the digital twin project and have helped us develop the methodology and procedures (Figures 11-13).

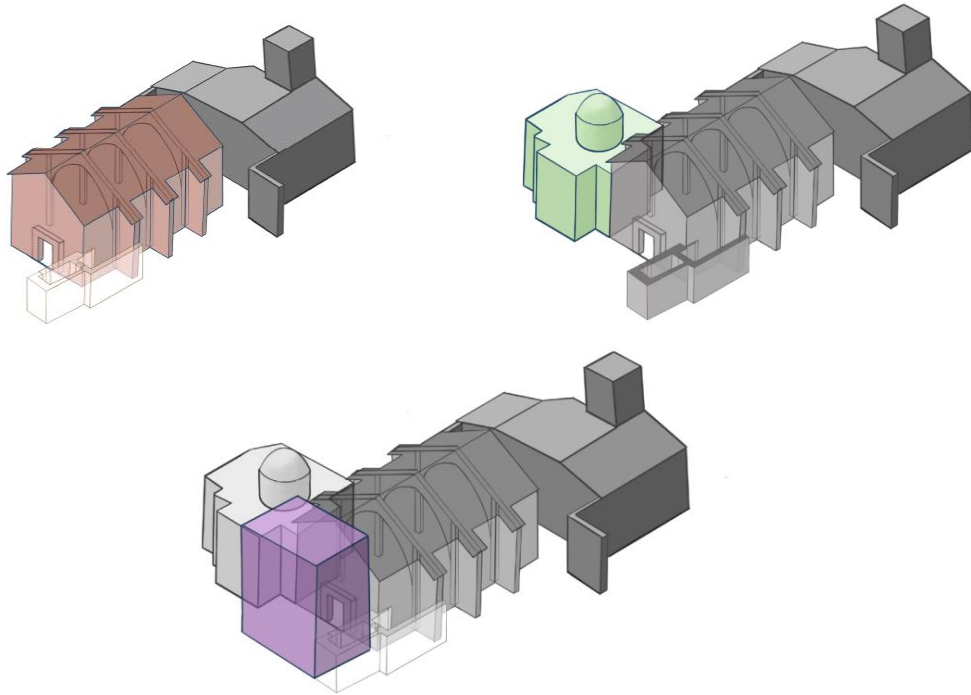


Figure 11: Volumes made with Procreate to understand the constructive hypotheses of the building.
Source: Blanco Estévez (2022).

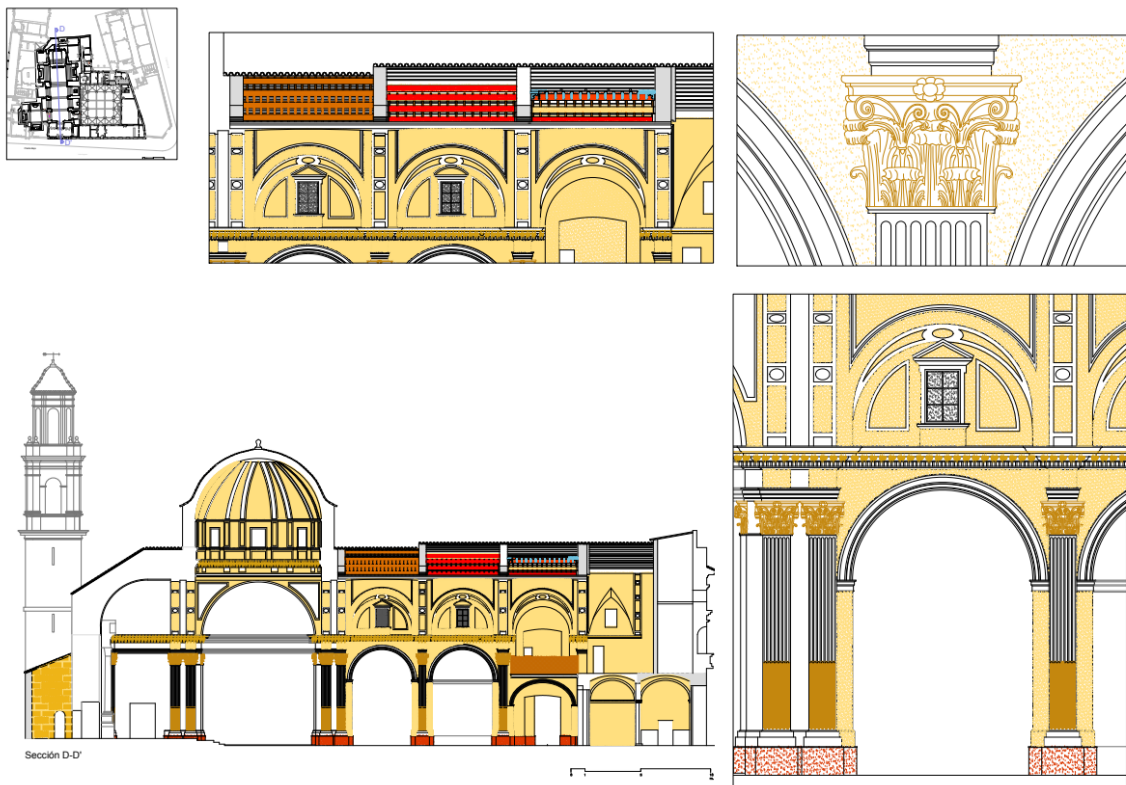


Figure 12: Section D-D' Church. Source: Blanco Estévez (2022).

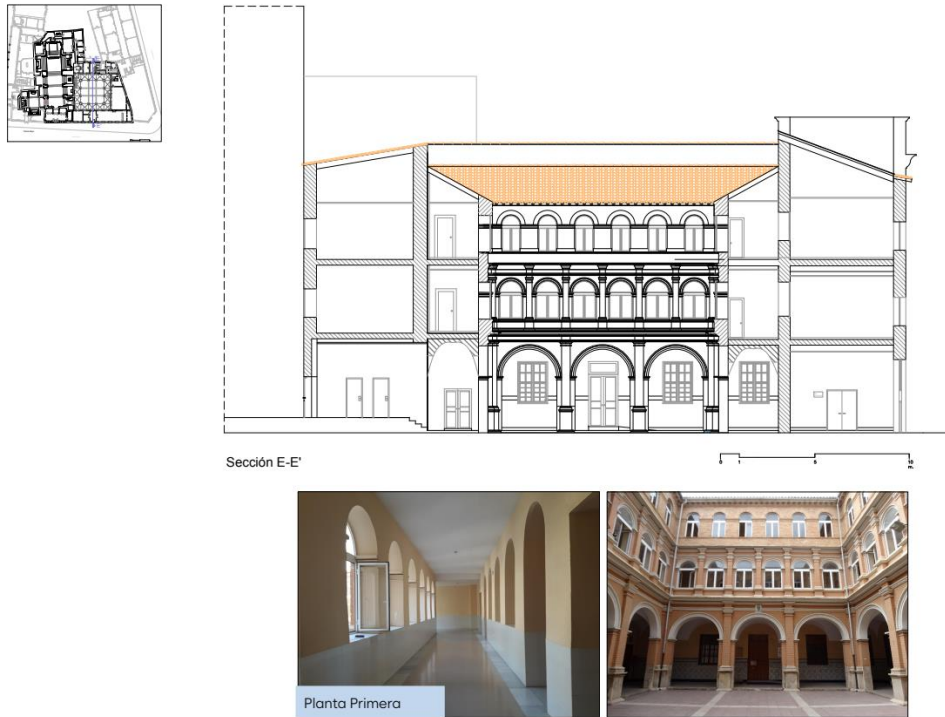


Figure 13: Section E-E' Church Source: Blanco Estévez (2022).

5. Conclusions

The digital twin is the base digital replica for its subsequent use as a tool for different purposes. It will always consider the type of heritage real estate and its casuistry, as well as its objective and its target audience.

Given the effort that it takes in time and economic cost, we must have a sense and, in turn, know very well what digital tools exist and which ones we can take advantage of. Always bear in mind that this is a field in constant evolution.

I believe that this asset is sufficiently relevant to make it necessary, once and for all, to give it the digital scope it needs, given the interest it arouses, the information available and the current technological possibilities.

6. Possible lines of research

6.1. Geographic information systems

Create a geographic information system (GIS) to place the monument in context and facilitate spatial data management. To do this, the monument is georeferenced, and geospatial data is obtained from maps, satellite images, topographic data, and document details. Using software such as QGIS, the data is imported to create layers that represent the monument and its context. The location can be compared with other adjacent/geospatial elements to create zones around the monument and evaluate its influence on the environment.

6.2. Analysis of the model and possible further uses

As has been said, it is aimed at the citizens, members, and owners of this building, and its potential usefulness is in the dissemination of a little-known asset of the city.

For example, if you have the 3D model, the point cloud of the roof, you could create a visual tour, for example, with Blender (once treated the cloud, obviously), which could be seen on the Internet, and that would allow you to know this Valencian treasure. The same is true for the church and the cloister.

Also, the digital twin could be used to motorise one of the biggest problems this monument has, which is rising dampness, by means of software that would indicate the humidity of the walls and if the current system with electro-osmosis works.

6.3. Accessibility

The model could be worked from this perspective:

- Enrich and connect: By indexing the features of the digital product, you give it value. Working to establish connections with other elements that share similarities ensures greater impact. In addition, it is crucial that the digital product can communicate effectively between different systems and formats.
- Open approach: It does not make sense to limit the use of the digital product. It must be designed to be accessible by different profiles within the Knowledge Society. In addition, its capacity to adapt to different social contexts is fundamental.

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