The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLVIII-2/W5-2024
International Workshop on "Photogrammetric Data Analysis" – PDA24, 7–9 October 2024, Moscow, Russia

The photogrammetric survey for the knowledge of religious spaces. Geometrical and dimensional analysis of the cloister

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Keywords: **S**urvey, Analysis, Geometry, Vaults, Religious Architecture
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Abstract

This research shows the photogrammetric survey and graphic documentation of the cloister of the Cathedral of the Assumption of the Virgin Mary and San Frutos in the city of Segovia, Spain.
The building consists of a series of architectural elements dating back to the Renaissance period. Segovia Cathedral, dedicated to Our Lady of the Assumption and San Frutos, is a masterpiece of Gothic and Renaissance architecture. It represents an icon of the Christian faith and a cultural-historical point in Spanish history.
The building was erected in the 16th century (1525-1577), when Renaissance architecture was flourishing in much of Europe. The research analyzes the context through the methodology of architectural drawing in order to propose knowledge and paths of fruition and enhancement. In the stages of the research, it was considered useful to divide the monumental building from the cloister in order to expand the possibilities of a more direct knowledge of the open layout towards the central courtyard. Particularly interesting is the system of vaults and buttresses that characterize the ceilings of the Cloister.
The results achieved highlight an understanding of the vaulted system in relation to the planimetric space, completely divorced from the city and able to allow the passage of the religious in moments of solitude and prayer.

1. Introduction (GG)

The contribution proposes the photogrammetric survey and graphic documentation of the cloister of the Cathedral of the Assumption of the Virgin Mary and San Frutos in the city of Segovia, Spain. Starting from the graphic and iconographic sources collected on site, the analysis presents the first stages of a broader study of both the Cathedral of Segovia, one of the last Gothic structures in Spain and Europe, and the cloister from an earlier period. As is well known, the building was built in the 16th century (1525-1577), when Renaissance architecture was flourishing in most of Europe. The research analyses the context through the methodology of architectural drawing in order to propose knowledge and paths of use and valorisation.
After the analysis of graphic and iconographic sources and historical documentation, information that contributed to the narrative of the Monument's transformations over the centuries, several survey campaigns were carried out to formulate the state of the sites of the few remains of the original structures that have survived to the present day.
As is well known, the old cathedral of Santa María de Segovia was destroyed in 1521, during the War of the Communities of Castile, where King Carlos I of Spain and V of the Holy Roman Empire, known as "the Caesar," ordered the construction of a new Cathedral, erected in one of the highest points of the city, between the old Santa Clara Convent and part of the Jewish quarter. The architect chosen was Juan Gil de Hontañón, and the first stone was laid on June 8, 1525, beginning construction from the western facade.

Figure 1. Segovia, the Cathedral, view from Plaza Mayor.

The building site was divided into three phases of construction: the first between 1525 and 1557 under architect Juan Gil de Hontañón, the second between 1578 and 1607 under Rodrigo de Solar, Juan Pescador, and Diego de Sisniega, and the last between 1607 and 1685 by Pedro de Brizuela. Construction events have significantly influenced the factory with remodelling starting from the year of construction.

Publisher's note: Copernicus Publications has not received any payments from Russian or Belarusian institutions for this paper.

This contribution has been peer-reviewed.
https://doi.org/10.5194/isprs-archives-XLVIII-2-W5-2024-61-2024

Figure 2. Segovia, the Cathedral, view of the intrados of the internal vaults.

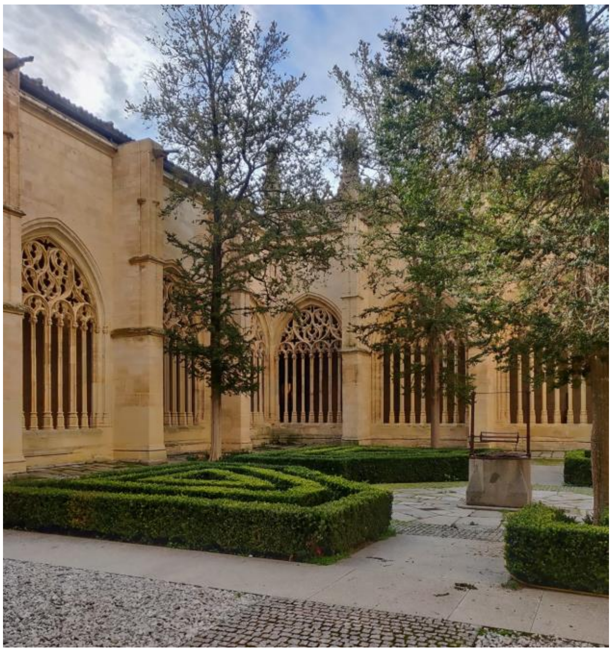

Figure 3. The Cloister of the Cathedral of Segovia in Spain, view of the interior space

Recent interventions to make use of the hypogeal spaces, with a museum of religious ornaments and vestments, occupy the basement floor that can be reached through a system of ramps and stairs that is integrated into the original structure.
In the research phases, it was considered useful to divide the monumental building from the cloister in order to expand the possibilities of a more direct knowledge of the open layout towards the central courtyard. Particularly interesting is the system of vaults and buttresses that characterise the ceilings of the cloister: load-bearing structures of majestic elegance realised using a stereotomic system that identifies the decorative elements in the ashlars and marbles. The results achieved highlight an understanding of the vaulted system in relation to the planimetric space, completely detached from the city and able to allow the passage of religious people in moments of solitude and prayer.

Figure 4. The Cloister of the Cathedral of Segovia in Spain, view of the vaulted side corridors

2. A few considerations on architecture and structures (GG)

The knowledge activities have enabled the reconstruction of the events that have characterised the building since its first construction. The building is, in fact, made up of a series of architectural elements dating back to the Renaissance period. Segovia Cathedral, dedicated to Our Lady of the Assumption and San Frutos, is a masterpiece of Gothic and Renaissance architecture.
Particularly interesting is the stratigraphic layout of, for example, the bell tower, dating back to the first construction phase (1525-1557) planned by architect Rodrigo Gil de Hontañón. The original drawing shows that the tower was crowned by a majestic wooden spire 27 metres high. As is well known, the element of the wooden spires was a central shaft extending from the base to the dome, around which the supporting structure, also made of wood, was built, covered with planks and molten lead. This became the main challenge that the master builder had to face: to reconcile the polygonal plan of the spire with the square top of the tower. This architectural challenge meant that the four sides of the spire had to be built on the four walls of the tower, completing the original profile of the medieval city of Segovia. The chosen drawing was by Juan del Pozo and the tower took 38 years to complete. On 18 September 1614, the wooden spire, covered with lead plates and culminating in a weathervane and a cross, was destroyed by a fire caused by lightning. The spire structure was replaced by an octagonal body and dome, planned by the Segovian Baroque architect Pedro de Brizuela. The project respects the four Gothic buttresses on which the wooden structure rested by incorporating them into the new construction.

3. The method for knowledge of places (LC)

The survey activities were carried out following the indications of the discipline of architectural drawing, with consolidated methodologies in the field of representation and processing of the collected data. To this purpose, a survey project organised on-site was drawn up based on the photographic images taken by Nikon reflex cameras: this activity allowed an initial phase of image-based knowledge of the cloister under investigation.

Figure 5. Segovia, the Cloister, cloud of points

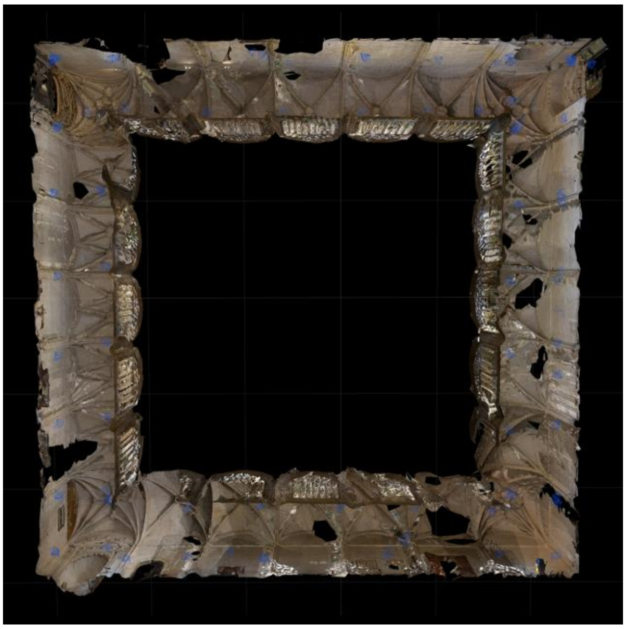

Figure 6. Segovia, the Cloister, cloud of dots, view from bottom

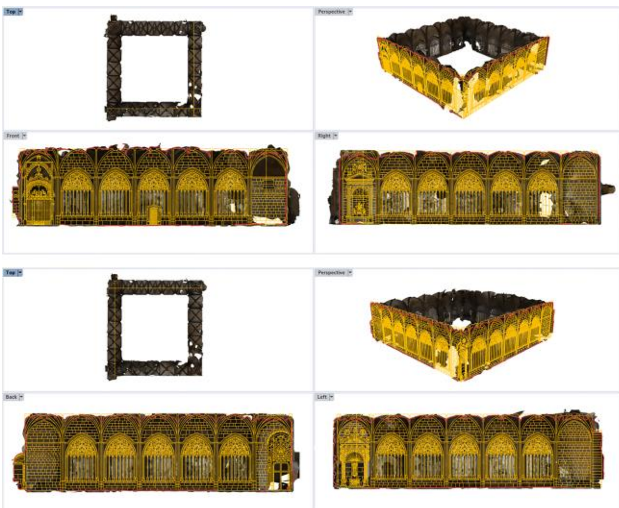

Figure 7. Parametric digital modelling of the Cloister of Segovia Cathedral.

Three actions were identified in the planning of the survey phases: the photogrammetric survey, the creation of point clouds and the processing of the collected data with dedicated digital software. A photogrammetric choice was therefore made as the distance between the points of capture and the architecture allowed the shots to be taken and overlapped. Drone shots, on the other hand, were not very constructive as the absence of satellite coverage hindered the creation of point clouds. In particular, it was decided to focus on the vaulted system, the construction-technological features, the ornamentation and decoration, and the colour features that form an integral part of the majestic cloister. The triangulation of the images in relation to the spaces, in fact, required greater attention as it was necessary to superimpose the shots and align them correctly already during the survey phase. The characterisation of the shots allowed the definition of certain image filtering procedures in order to determine the greatest noise reduction, caused mainly by the flow of onlookers and tourists crowding the space. Digital processing with photogrammetric software made it possible to obtain high-density point clouds, meeting the needs and requirements of site documentation.

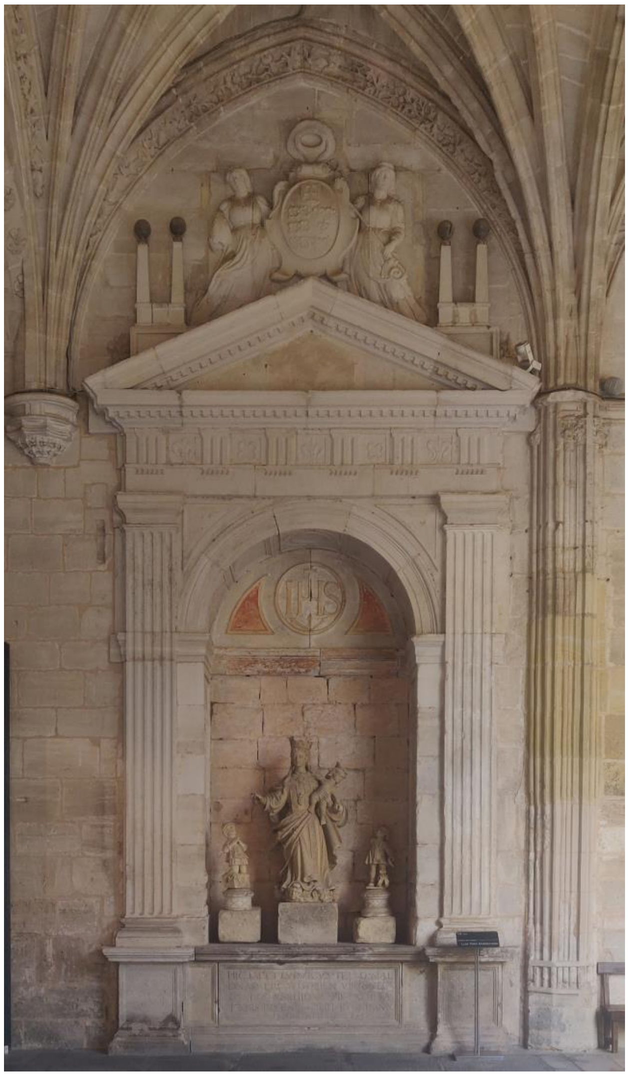

Figure 8. Segovia, the Cloister, view of the detail of the side altars

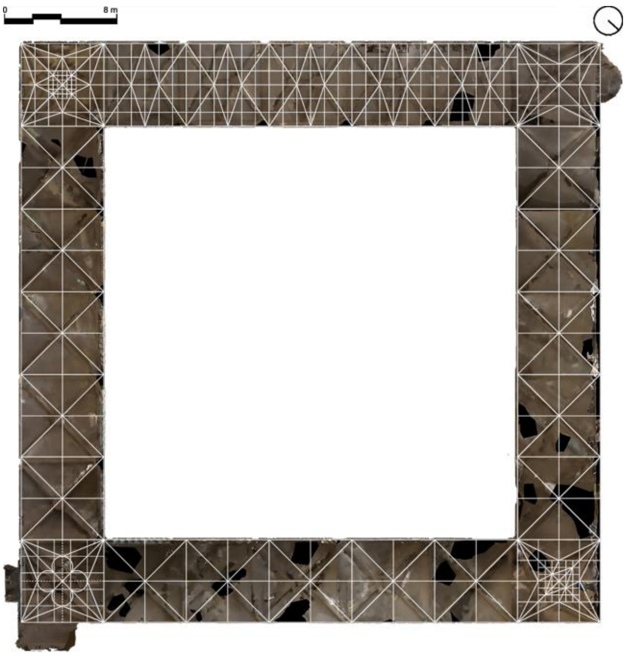

Figure 9. Intrados of the vaulted system of the cloister of Segovia Cathedral. Geometrical analysis and identification of the load-bearing system.

Figure 10. Segovia, the Cloister, view of the detail of the side altars

Figure 11. Detail of the vaulted system of the cloister of Segovia Cathedral.

This procedure accomplished the acquisition and management of three-dimensional georeferenced data through a four-step process: photo alignment, dense cloud construction, mesh construction, and texture construction. Point cloud development included several activities: evaluation of parameters (such as focal length and radial and tangential distortions), determination of camera positions for each shot, and creation of the point cloud. Next, the number of pixels for each aligned camera was increased to generate the dense cloud. A polygonal mesh was then created based on the dense cloud data, and finally, the textured polygonal model was defined in the texture construction phase. The polygonal model was then imported into Rhinoceros software for graphical rendering of the data, using cutting planes for the interior visualization of the Cloister. This activity allowed the extrapolation of the two-dimensional drawings useful for the knowledge and enhancement of the site. In fact, the resulting geometric study of the vaulted system was carried out by superimposing an orthogonal mesh on the previously drawn-up graphic base

4. The vaulted system: survey and analysis of the cloister (LC)

In the analysis of the cloister space, a geometric representation of the vaulted system was carried out. The general characters were identified, consisting of squares (a) and squares divided in half (a/2), which constitute the orthogonal mesh system supporting the entire construction. The cloister, in addition to having a connecting function between the main church and the secondary religious structure, represented the place of transit for the religious between services and times of prayer.
The square planimetric base is characterised by a cross-shaped system with a central well and four pathways connecting with the centre of the side elevations. The screening system between the exterior and interior of the corridor not only represents a

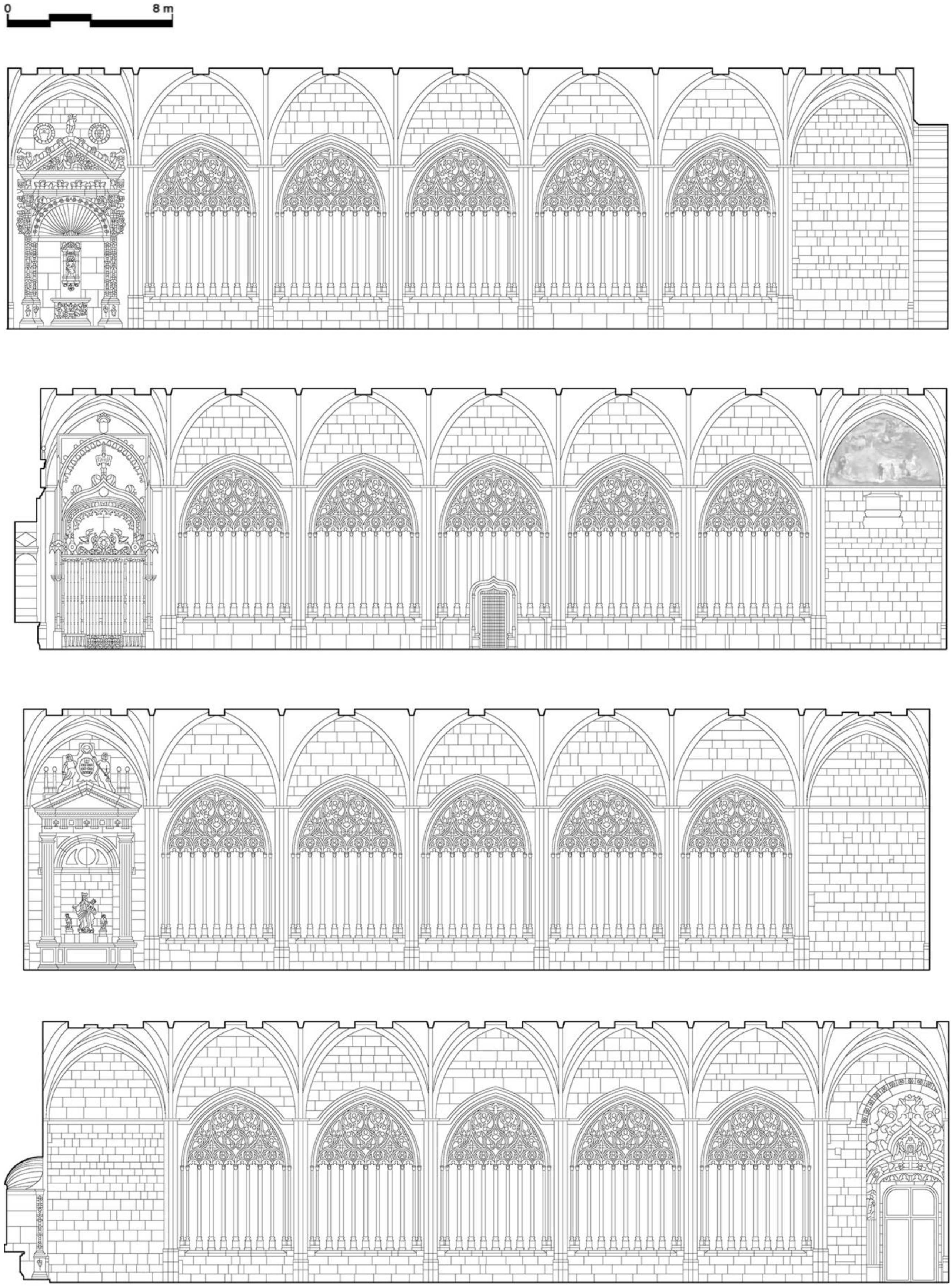

Figure 12. Survey of the interior elevations of the Cloister of Segovia Cathedral. From the top north-west section, south-west section, south-east section, north-east section.

barrier between the architecture and nature, but also filters light and weathering towards the local stone flooring system.
The drawing of the ground triggers a process of union between stone formats of different cuts: there is no water collection gutter at the base of the large openings facing the internal courtyard.
The windows with a pointed arch system at the top are divided by seven small columns and two half pilasters supporting the stone frieze placed at the top. The columns are surmounted by carved capitals decorated with floral and geometric motifs. The decorative layout is characterized by a geometric repetition of known figures on four orders at the base and an arabesque-type system connected by stone whorls to the underlying construction system.
The cloister consists of a set of 24 square vaults, 15 of which are simple cross vaults, while the remaining 9 are star vaults. It should be noted that among the 9-star vaults, those located at the four corners of the cloister show geometric-structural differences between them. The vault at the west vertex of the cloister is characterised by a form that is very common throughout Europe, and Guas has made no significant transformations to it. It is based on a 4x4 grid in which he placed some ribs, articulated by four ribs that join the contact points of the crescents with the central keystone.
The vault in the north vertex, on the other hand, has an original drawing, in that the diagonal ribs do not reach the centre but bifurcate to form the sides of a rhombus, lacking, therefore, a central keystone, which is replaced by another placed at each vertex of the rhombus. In the south vertex, on the other hand, the grid is 6x6, with the union point of the triplets at the centre of the parallel closest to the sides and, consequently, at 1/3 of the side and 2/3 of the centre of the vault, so that the star is much more open than the two previously mentioned. The last vault, in the east vertex, corresponds to the entrance vault and is based on a 5x5 grid, with the union points at the midpoint of each parallel closest to the sides, so that the star has an intermediate opening.

5. Conclusions (LC & GG)

The contribution of the survey for the analysis and knowledge of the Cathedral of the Assumption of the Virgin Mary and San Frutos has been a foundational part of the process of investigation for the enhancement of historic architecture. The building represented a factory of stratigraphic, geometric, and mathematical interventions for the description of the Gothic-Renaissance structure in the Spanish territory. This activity constitutes a small part of the possible survey interventions to be carried out later on both the Cloister and the entire Cathedral. The geometric matrixes surveyed are the result of several studies conducted on courts and cloisters in Spain and Portugal with similar examples in the two countries. Possible future developments are both the realization of the entire survey of the structure and its comparison with coeval examples, and further colorimetric analyses to be held in the Cloister.

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