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# PENSAR DIBUJANDO

VALVERDE, CAÑIZARES, BARRERA, RODRÍGUEZ (EDS.)



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## Presentación

Con esta publicación se culmina el trabajo del congreso APEGA (Asociación de Profesores de Expresión Gráfica Aplicada a la Edificación), cita bienal que reúne a los expertos y profesores del área que imparten docencia e investigan en las distintas Universidades y Escuelas de Europa y América, fundamentalmente. Sirve de vehículo para el intercambio de conocimiento y experiencias con el objetivo de fomentar, potenciar, orientar, desarrollar y promover la enseñanza de la EXPRESIÓN GRÁFICA en las titulaciones universitarias de Arquitectura Técnica, Ingeniería de Edificación y demás titulaciones del ámbito de la edificación.

En las quince anteriores publicaciones de APEGA se establecieron las bases con las que pretendemos la realización de proyectos conjuntos que permitan obtener resultados relevantes en el ámbito de la Expresión Gráfica en la Edificación, proyectos que contribuyan y conduzcan hacia una producción científica de calidad e interés internacional. La continuidad de estas publicaciones de resultados científicos durante tantos años atestigua el éxito de la iniciativa que no se vio interrumpida ni siquiera en años de pandemia y crisis.

En tiempos de inteligencia artificial y reuniones virtuales, la presencia física en los congresos, con oportunidad de discutir y defender propuestas en vivo y en directo, ofrece un nuevo valor a la investigación del que carecen los actualmente reinantes artículos de revistas. De ahí el interés de esta publicación que combina la evaluación del comité científico con la presentación y discusión de las propuestas entre congresistas y ponentes.

PENSAR DIBUJANDO es el lema elegido para la presente edición y propone una estructura transversal de las líneas temáticas de las comunicaciones. Se parte, como premisa, de que la imagen final, el dibujo, es para la expresión gráfica aplicada a la edificación, no tanto un fin en sí misma, sino un vehículo útil para el exhaustivo análisis y/o producción de lo representado; infiriéndose de ella que precisa, para alcanzar dicho objetivo, extraer la esencia de la realidad de forma previa a su dibujo o modelización.

Esta es la secuencia necesaria que pretende reflejar la publicación: desde la síntesis a la realidad, que es la que inspira tanto el lema del Congreso, PENSAR DIBUJANDO, como la estructura transversal establecida en la publicación.

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## Índice

REPRESENTATION AND PERSONALIZATION OF SPACE IN SCHOOL CLASSROOMS .....	1
<i>Sebastián Alcaraz García, Amparo Verdú-Vázquez, Tomás Gil-López</i>	
EXPLORING ENVIROMENTAL AWARENESS IN THE CLASSROOM THROUGH GRAPHIC EXPRESSION: PERCEPTIONS FROM PRIMARY AND SECONDARY SCHOOL STUDENTS .....	13
<i>Sebastián Alcaraz García, Amparo Verdú-Vázquez, Tomás Gil-López</i>	
ARCHITECTURAL SURVEY TECHNIQUES APPLIED TO SACRED TEXTILE ART .....	24
<i>Daniel Antón, Miguel León-Muñoz, Margarita Infante-Perea, Juan Jesús Martín-del-Río, Concepción Cantillana-Merchante</i>	
THREE-DIMENSIONAL EXPLORATION OF THE COSMIC CITY BY IANNIS XENAKIS .....	35
<i>Felipe Asenjo Álvarez, Susana Moreno Soriano, Diego García Cuevas, Jorge Cerdá Inglés</i>	
THE GRAPHIC EXPRESSION APPLIED TO BUILDING IN THE CURRICULAR SUSTAINABILIZATION PROCESS .....	43
<i>Amparo Bernal López-Sanvicente</i>	
THE DESIGN FOR THE KNOWLEDGE AND TRANSFORMATION OF REALITY .....	52
<i>Emanuela Borsci</i>	
CHATGPT. IMPLICACIONES EN LA ENSEÑANZA DE INGENIERÍA Y EDIFICACIÓN .....	62
<i>Elena Cabrera Revuelta, José Antonio Barrera Vera, Ángel José Fernández Álvarez</i>	
SURVEY OF LINEAR CONSTRUCTIONS WITH PORTABLE DYNAMIC LASER SCANNER SYSTEMS (WMMS). OPTIMISATION OF THE PROCESS TO OBTAIN THE GEOMETRY OF A SECTION OF THE USSEIRA AQUEDUCT, PORTUGAL .....	70
<i>Francisco Javier Chorro Domínguez, María José Marín Miranda, Paula Redweik, José Juan de Sanjosé Blasco</i>	
EXPERIENTIAL CARTOGRAPHIES: MAPPING THE SENSORY, THE AFFECTIVE AND THE DYNAMIC .....	78
<i>Virginia De Jorge Huertas, Raúl Torres Guzmán</i>	
DISCOVERING BEAUTY. ARCHITECTURE IN THE CHURCHES OF THE PROVINCE OF CUENCA .....	89
<i>Juan José de Julián Muelas</i>	
THE BUILDINGS OF THE 1929 EXHIBITION AS INSPIRATION FOR THE DESIGN OF THE GATEWAYS OF THE SEVILLE APRIL FAIR .....	101
<i>Pablo Díaz Cañete, M. Luz Saracho Villalobos, M. Dolores Rincón Millán, Rafael Esteve Pardal</i>	
HBIM APPLIED TO THE DOCUMENTATION OF ALTARPIECES. THE ALTARPIECE AS A DIDACTIC RESOURCE .....	112
<i>Silvia Díaz Parrilla, Antonio Jesús Sánchez Fernández</i>	
MORPHOLOGICAL MODELS IN AUTOCAD WITH BIM METHOD FOR CIVIL ENGINEERING .....	122
<i>Andrea Donelli</i>	

CHROMATIC RECOVERY STUDY OF THE CHAPEL OF SAN ANTONIO DE PADUA OF THE HERMITAGE OF THE VIRGEN DE LA HUERTA, (ADEMUZ) VALENCIA .....	132
<i>María de los Ángeles Dorantes Lámbarri, Ana Torres Barchino, Irene de la Torre Fornés</i>	
TEARS OF ARCHITECTURE. MICROGRAPHS OF INTANGIBLE SPACE .....	141
<i>María I. Fernández Naranjo, Tomás García García</i>	
ANALYSIS OF THE WORK OF FRAY LORENZO DE SAN NICOLÁS IN TALAVERA DE LA REINA .....	153
<i>Josefina García-León, Josefa Ros Torres, Jaime Fernández Vázquez, Miguel García Córdoba</i>	
ADVANCES IN LEARNING BASED ON PROJECT MANAGEMENT APPROACHES APPLIED TO THE TEACHING OF ARCHITECTURAL DRAWING I .....	162
<i>Jorge García Valldecabres, Jorge Gurbés Pérez, María Concepción López González</i>	
THE GRAPHIC SURVEY OF THE HERITAGE CERAMIC PAVEMENT OF THE 16TH CENTURY TO THE PAVEMENTS OF THE 20TH CENTURY .....	171
<i>Jorge Gurbés Pérez, María Concepción López González, Jorge García Valldecabres</i>	
GRAPHIC SURVEY AND ARCHITECTURAL ANALYSIS OF THE NORTHERN DOORWAY OF THE CHURCH OF SAN MIGUEL DE JEREZ DE LA FRONTERA (CÁDIZ) .....	181
<i>José María Guerrero Vega, Miguel Redondo Redondo</i>	
FROM TRADITION TO MODERNITY, LE CORBUSIER'S SKETCH AS A TOOL TO DESIGN THE CAPITOL OF CHANDIGARH .....	189
<i>Álvaro Hidalgo Núñez, Francisco Antonio Hidalgo Núñez, Marina Sender Contell, Santiago Lillo Giner</i>	
LANDSCAPE AS THE BASIS OF ARCHITECTURE .....	196
<i>Francisco Hidalgo Núñez, Álvaro Hidalgo Núñez, Marina Sender Contell, Santiago Lillo Giner</i>	
ARTIFICIAL INTELLIGENCE FOR THE TEACHING OF GRAPHIC EXPRESSION .....	205
<i>Pablo Juan Gutiérrez, Sergio García Doménech, Ramón Maestre López-Salazar</i>	
THE "PORTAL DEL MAR" OF VALENCIA. A FORTIFIED ACCESS TO THE CITY .....	213
<i>Santiago Lillo Giner, Francisco Hidalgo Núñez, Álvaro Hidalgo Núñez, Manuel Giménez Ribera</i>	
THE NECESSITY OF DRAWING FOR THE DOCUMENTATION AND TEACHING OF CONSTRUCTION. OF CONSTRUCTION. THE BEGINNING OF ARCHITECTURAL TREATISES IN SPAIN .....	223
<i>Santiago Llorens Corraliza</i>	
THE RELIGIOUS HERITAGE OF RECONQUISTA. CASE STUDY .....	234
<i>María Concepción López González, Jorge García Valldecabres, Jorge Gurbés Pérez</i>	
NATURAL LIGHTING IN A RENAISSANCE TEMPLE .....	242
<i>María Jesús Máñez Pitarch, José Teodoro Garfella Rubio</i>	
GRAFIC SURVEY METHODOLGY WITH LASER DISTANCE METER. THE HELICAL STAIRCASE OF THE CHURCH OF SANTIAGO. CÁCERES .....	251
<i>María José Marín Miranda, Francisco Javier Chorro Domínguez, Antonio Romero Casado, Juan Saumell Lladó</i>	
EXPERIENCES OF THE TRANSITION PROCESS TOWARDS THE CAPTURE AND GRAPHIC REPRESENTATION OF PRECISION IN BUILDING .....	260
<i>Alexander Martín-Garín, Iñigo León-Cascante, María Senderos-Laka, José Javier Pérez-Martínez</i>	

ANALYSIS AND TERRITORIAL EVALUATION THROUGH SOCIAL-HOUSING SPATIAL SEGREGATION AND GIS USE APPLIED TO THE CITY OF CHOLUTECA (HONDURAS) .....	270
<i>Francisco Maza Vázquez, Nadia Melissa Cruz Elvir</i>	
GEOMETRIC DECISIONS FOR THE PARAMETRIC DESIGN OF AN EXPERIMENTAL STRUCTURE. A CASE STUDY OF THE ARCHIMEDEAN PAVILION .....	278
<i>Roberto Narváez-Rodríguez</i>	
DRAWING, DESIGN, SURVEYING: COGNITIVE PATHS FOR THE ANALYSIS OF AN ELEVATED RAILWAY STATION IN ITALY .....	289
<i>Caterina Palestini, Giovanni Rasetti, Lorenzo Pellegrini</i>	
3D REPOSITORY FOR THE ENHANCEMENT OF THE CULTURAL ROUTE OF JAIME I IN VALENCIA .....	299
<i>Francesca Picchio, Luis Cortés Meseguer, María Concepción López González, Jorge García Valldecabres, Alberto Pettineo, Anna dell'Amico, Fu Hangjun, Francesca Galasso</i>	
STUDIES ON CARTOGRAPHY AND SPATIAL INFORMATION SYSTEMS AS KNOWLEDGE RESOURCES NEEDED IN BUILDING AND ARCHITECTURE DEGREES .....	310
<i>Miguel Redondo Redondo, José María Guerrero Vega</i>	
DIGITAL SURVEY TECHNOLOGIES IMPLEMENTED IN VIRTUAL REALITY: MONASTERY OF SAN JERÓNIMO DE BUENAVISTA IN SEVILLE .....	320
<i>Fernando Rico Delgado, Pablo Díaz Cañete, M. Rosario Chaza Chimeno, Jorge Veiga Castro</i>	
METHODOLOGIES FOR THE COMPREHENSIVE GRAPHIC SURVEY OF CASTLES LOCATED IN COMPLEX SITES .....	330
<i>Pablo Rodríguez-Navarro, Teresa Gil-Piqueras, Alba Soler Estrela</i>	
COMPUTATIONAL METODOLOGIES FOR THE ARCHITECTURAL SURVEY OF THE HERITAGE .....	339
<i>Andrea Ruggieri</i>	
SURVEY AND REPRESENTATION OF FUNERARY ARCHITECTURES: THE EVANGELICAL CLOISTER IN THE CHARTERHOUSE OF BOLOGNA .....	352
<i>Michele Russo, Paolo Fregomeni, Sergio Cariani</i>	
INTERACTIVE VIRTUAL ENVIRONMENTS: FROM MODELLING TO ARCHITECTURAL EXPLORATION .....	362
<i>Anna Sanseverino, Carla Ferreyra, Victoria Ferraris</i>	
THE URBAN AND ARCHITECTURAL RENEWAL OF GUADALAJARA FIRST THIRD OF THE 20TH CENTURY .....	374
<i>Antonio Miguel Trallero Sanz, Antonio Miguel Trallero Arroyo</i>	
POPULAR EDUCATION IN ITALY THROUGH THE ILLUSTRATED PRESS OF THE EARLY 19th CENTURY .....	387
<i>Pasquale Tunzi</i>	
VIRTUAL REALITY: OPPORTUNITIES FOR IMPLEMENTATION IN THE AREA OF GRAPHIC EXPRESSION .....	397
<i>M. Mercedes Valiente López, Manuel Álvarez Dorado, Alicia Zaragoza Benzal, Carolina Piña Ramírez, Alejandra Vidales Barriguete</i>	
BUILDING INFORMATION MODELING FOR PRECAST CONCRETE COMPONENTS IN DEVELOPED NATIONS .....	406
<i>M. Mercedes Valiente López, Amirhossein Javaherikhah</i>	



## **SURVEY AND REPRESENTATION OF FUNERARY ARCHITECTURES: THE EVANGELICAL CLOISTER IN THE CHARTERHOUSE OF BOLOGNA**

### **ESTUDIO Y REPRESENTACION DE LAS ARQUITECTURAS FUNERARIAS: EL CLAUSTRO EVANGELICI DE LA CARTUJA DE BOLONIA**

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#### **Abstract**

The survey, representation, and analysis of portions of monumental cemeteries is an open topic. These areas were introduced in Italy between 1804 and 1814 following the Napoleonic edict, defining very interesting architectonic and sculptural spaces. Over two centuries, the need to begin preliminary work to analyze surface and structural deterioration often becomes essential, defining strategies for conservation and intervention. In this cognitive process, the use of 3D surveying methodologies allows the acquisition of these complex spaces, enabling their interpretation and analysis of shapes by drawing. The case study discussed is the Cloister of the Evangelicals or A Catholics, built in Bologna in 1822 and dedicated to people of faith other than Roman Catholic. The space is within the cemetery of the Certosa di Bologna, founded in 1801, and the container of a vast heritage of paintings and sculptures and a UNESCO World Heritage Site since 2021. The research illustrates, on the one hand, the process of data acquisition and restitution, which allowed us to define the basis for mapping and analysis of the state of structural conservation. However, the complexity level and the scale variation define bottlenecks in both acquisition and restitution. Some formal rules and exceptions are also highlighted through a geometric-proportional analysis, showing a complete path of reading and analysis of an example of funerary architecture.

**Keywords:** 3D Acquisition, Funerary Representations, Geometrical Analysis, Conservation Mapping.

#### **Resumen**

El estudio, la representación y el análisis de partes de cementerios monumentales es un tema abierto. Estas áreas se introdujeron en Italia entre 1804 y 1814 a raíz del edicto napoleónico, definiendo espacios arquitectónicos y escultóricos de gran interés. A lo largo de dos siglos, la necesidad de iniciar trabajos preliminares para analizar el deterioro superficial y estructural se hace a menudo imprescindible, definiendo estrategias de conservación e intervención. En este proceso cognitivo, el uso de metodologías de digitalización 3D permite la adquisición de estos espacios complejos, posibilitando su interpretación y el análisis de las formas mediante el dibujo. El caso de estudio analizado es el Claustro de los Evangélicos o Acatólicos, construido en Bolonia en 1822 y dedicado a personas de fe distinta a la católica romana. El espacio se encuentra dentro del cementerio de la Certosa di Bologna, fundado

en 1801, y contenedor de un vasto patrimonio de pinturas y esculturas y Patrimonio de la Humanidad de la UNESCO desde 2021. La investigación ilustra, por un lado, el proceso de adquisición 3D y restitución de datos, que permitió definir las bases para la cartografía y el análisis del estado de conservación estructural. Sin embargo, el nivel de complejidad y la variación de escala definen cuellos de botella tanto en la adquisición como en la restitución. También se destacan algunas reglas formales y excepciones a través de un análisis geométrico-proporcional, mostrando un recorrido completo de lectura y análisis de un ejemplo de arquitectura funeraria.

**Palabras clave:** Digitalización 3D, Representaciones Funerarias, Análisis Geométrico, Mapas De Conservación.

## 1. Introduction

Architectural survey and representation techniques have reached an extremely high level of reliability. The application of increasingly high-performance active and passive 3D acquisition tools allows for capturing many shapes in the space at different levels of detail. In continuity, tools for data restitution enable the handling of vast amounts of heterogeneous information, defining the virtual context of interpreting the real object. In this well-established scenario, the research of a balance between the characteristics of the case study and the purpose of the survey and restitution process plays a central role, leading to optimized methodological solutions that fit the specific asset. Thus, the case study and its specificity are crucial in defining the survey methodology and choosing how to represent and analyze the architecture. In this sense, portions of monumental cemeteries are still an open issue, explored in depth by the research presented in the article. Monumental cemetery areas appear as a mix of architectural systems and sculptural examples, defining a strong variation in scale. Introduced in Italy between 1804 and 1814, over time they have acquired a central role in urban areas from many points of view. However, the need to start the analysis of surface and structural degradation has become an increasingly compelling requirement to define strategies for the conservation and intervention of these essential areas. In this cognitive process, the integrated use of 3D surveying methodologies is necessary to acquire these complex spaces, opening interpretation and shape analysis scenarios by drawing and representation instruments. This research analyzes the Cloister of the Evangelicals or A Catholics, framed within the cemetery of the Certosa of Bologna, founded in 1801 and declared a UNESCO World Heritage Site in 2021. The study deepens the data acquisition and restitution process, which made it possible to define the basis for mapping and analyzing the state for its structural conservation. Besides, formal rules are highlighted through a geometric-proportional analysis, showing a complete path of reading and research. The goal is to convey attention to a "minor" architectural typology by surveying, drawing, and representing activities, creating an updated and reliable knowledge model.

## 2. The Funerary architecture

The subject of funerary architecture is a vast field, spanning cultures, historical periods, and territories, expressing through monumental examples one of the high points of the period's architecture. Monumental Cemeteries were introduced in Europe after the 1800s as an answer for the post-Napoleonic bourgeoisie to give relevance to their burials without being able to afford devoted chapels. The Père-Lachaise in Paris, erected in the early XIX century, marks the birthplace of cemeteries decorated with large sculptures and monuments. From that time, other similar examples sprang up all over Europe. In Italy, the nation with the highest number of them on the continent, the famous Vantiniano in Brescia, the first monumental cemetery in the history of art, the Milan cemetery, the Pavia cemetery, the Messina cemetery, and the Staglieno cemetery were built. Following the period's style, these cemeteries became a territory of architectural experimentation for many architects (Fig. 1). In the early 2000s, the first associations to protect and enhance monumental cemeteries were

born. In Italy in 2016, a memorandum of understanding was signed defining monumental cemeteries as part of Italy's historical heritage. These conditions, combined with the need to preserve and conserve these places, a symbol of material and intangible culture for many cities, have led to many conservation and restoration projects in the last two decades. The geometric and textural 2D/3D survey is crucial in this knowledge pipeline, even if it can present multiple bottlenecks due to the variation in scale, acquisition conditions, and the presence of multiple materials [3]. Despite this level of richness and complexity, monumental areas have never gained much interest from the scientific community [1], [8], unlike, for example, hypogea [5] or specific monuments that are complex and dedicated to specific people [6]. The research about the Certosa di Bologna stems from the same desire to initiate a general program of analysis, restoration, and redevelopment of the Monumental Property of the area following the seismic events 2012.



Fig. 1. Images of monumental cemeteries: a) Vantiniano cemetery (Brescia); b) Milan cemetery; c) Verano cemetery; d) Staglieno cemetery.

## 2.1. The Charterhouse of Bologna

The Certosa cemetery in Bologna [4] was founded in 1801 by reusing the structures of the Carthusian convent built in 1334 and suppressed in 1796 [7]. The church of San Girolamo represents the lost importance of the convent. The fulcrum of the cemetery is the *Chiostro Terzo*, an accurate result of the local neoclassical culture where the initially painted tombs were later replaced by works in stucco and scagliola and - starting in the mid-19th century [2] - in marble and bronze.

The complex over the centuries results from an intricate layering of loggias, cloisters, and buildings ranging from the 15th century to the present, gradually taking on characters of progressive breadth and monumentality. The interior preserves a vast patrimony of paintings and sculptures created by almost all the Bologna artists active in the 19th and 20th centuries, evidence of the complex artistic, historical, and intellectual events of Bologna. Since 2021, the Certosa di Bologna has been declared a UNESCO World Heritage Site as part of the "Portici di Bologna" project (Fig. 2).





Fig. 2. Satellite view of the Charterhouse area (source: Google Earth) and from RPAS.

## 2.2. The Evangelical Cloister

Along the driveway leading to the entrance of the Charterhouse, on the west side, there is access to a small enclosure: the Cloister of the Evangelicals or A Catholics, dedicated to people of faiths other than Roman Catholic. Its purpose of the use is justified by the fact that, after the Jacobean period and with the return of the papal government in 1815, it was decided to subdivide the Charterhouse with camps and cloisters to accommodate different types of people. Today the area is bounded by four sides, three of which are enclosed by a simple and elegant Doric-style portico, and the fourth side is formed by the enclosure wall overlooking the driveway to the Charterhouse. To the north of the Cloister is a small enclosure that now preserves no burial grounds. Initially, It was reserved for burying prisoners, condemned, and executed. The Cloister initially (Fig. 3) consisted of three areas devoted to burial, with separate entrances. From the research, several transformations over time are collected mainly into four phases (Fig. 3):

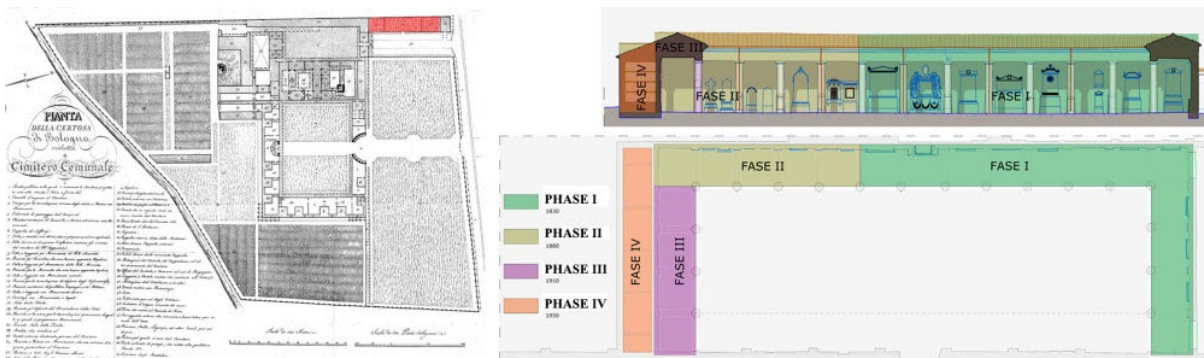


Fig. 3. On the left historical plan by Giovanni Zecchi (1828-29), on the right the 4 main historical phases.

- PHASE I: Original body: Built presumably between 1820 and 1840, it consisted of the north colonnaded body and partially the east colonnaded body. The original body already had the three central bays of portico aligned with the present gate (axis of symmetry).

- PHASE II AND PHASE III: Completion of the original body, with the construction of the remaining east colonnade, presumably made in 1880-1890, and later the new south colonnade body. While respecting the existing compositional typology, the south part used modern techniques, such as the external concrete entablature, and valuable finishes, such as the capitals of the pilasters in sandstone instead of plaster. These features place it in the early decades of the 1900s (1930-1940). This constructive asymmetry, highlighted by the materials, is amplified by the tympanum.

- PHASE IV: Extension involving the construction on the outer side of the south body of a later volume for wall burial niches. The intervention refers to the 1950s.

These phases are complemented by various interventions over time (Fig. 4), some of which compromised the system's stability along with the 2012 earthquake.



Fig. 4. Ground and drone images of the cloister.

### 3. Data Acquisition

Besides the iconographic and historical research completed to understand the evolution of the building, several survey and analysis campaigns were planned to gather as much information as possible for the consolidation and restoration project. For the sake of brevity, some of the analyses performed are listed below:

- Geometric and radiometric 3D survey of the entire area;
- Stratigraphic research of the films and finishes;
- Visual analysis of building elements by field surveys.
- Analysis of masonry and steel materials to assess seismic and structural vulnerability.

The geometric survey enabled annotation by mapping all information acquired in the field. This phase is discussed in more detail below.

#### 3.1. Geometrical survey

During the design and execution of the survey, the high variation in scale and the presence of many shaded areas, created by both the colonnade and the tombs and lush vegetation, have been carefully considered. The survey planning involved the integration of active (phase variation 3D laser scanner) and passive (ground and drone photogrammetry) sensors. The 3D laser scanner (RTC360, Leica) enabled the rapid acquisition of the entire area, taking



advantage of real-time point cloud pre-alignment using VIS technology, which recognizes the instrument's movements in space by cameras.

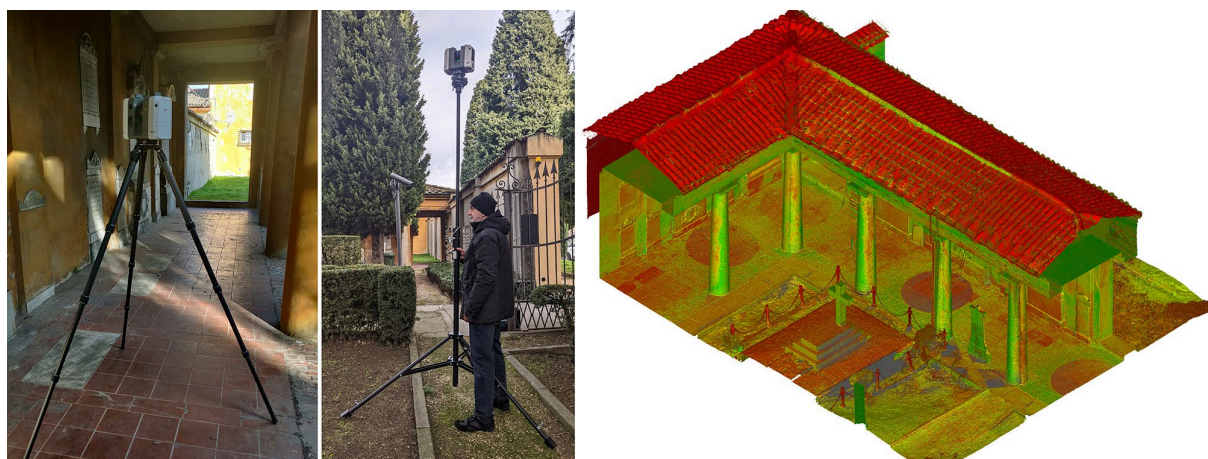


Fig. 5. Range-based acquisition phases and axonometric view of the point cloud of one cloister area.



Fig. 6. Ground and drone orthophotos of the cloister and deep map extracted from the point cloud.



Forty-two scans were acquired, most from the ground and some at 3 meters, thanks to a special tripod (Fig. 5). The clouds were aligned with an error of 5 mm, resulting in a final cloud of about  $1.1 \times 10^9$  points that were subsampled at 5 mm resolution to optimize its handling. The data acquired with the laser scanner were used as a reference for the orientation of the photogrammetric images.

The RPAS photogrammetric acquisition project involved using the inoffensive Mavic Mini 2 (DJI) drone, which mounts an FC 7303 camera with a 3000 x 4000 pixel sensor and a 4.5 mm focal length. Two flights were planned at 50 and 20 meters altitudes, the first to frame the general area with a 14 mm GSD. The second, however, was devoted to the Cloister, with a GSD of 2.8 mm. Following an overlap of 60% and 80% in the two different directions, 285 images were acquired. Ground-based images were acquired with a rod using a DSC-HX60 camera (Sony) with a sensor of 5184 x 3456 pixels and a focal length of 4.5 mm to acquire the inner porch. The shooting distance of 7 meters from the bottom and 3 meters from the façade resulted in a GSD of 2 mm and 0.8 mm, respectively, acquiring 224 images. All images were oriented in the same 3D laser scanner reference system using 11 physical points acquired with the range-based system (Fig. 6).

#### 4. Data Representation and Analysis

The integrated point cloud and orthophotos produced by the photogrammetric model defined the database for the architectural representation of the Cloister. The richness of the details and the need to map the entire crack framework required a 1:50 and 1:20 scale representation (Fig. 7). Some peculiarities, such as the truncated cone columns, were found during this latter (Fig. 7).

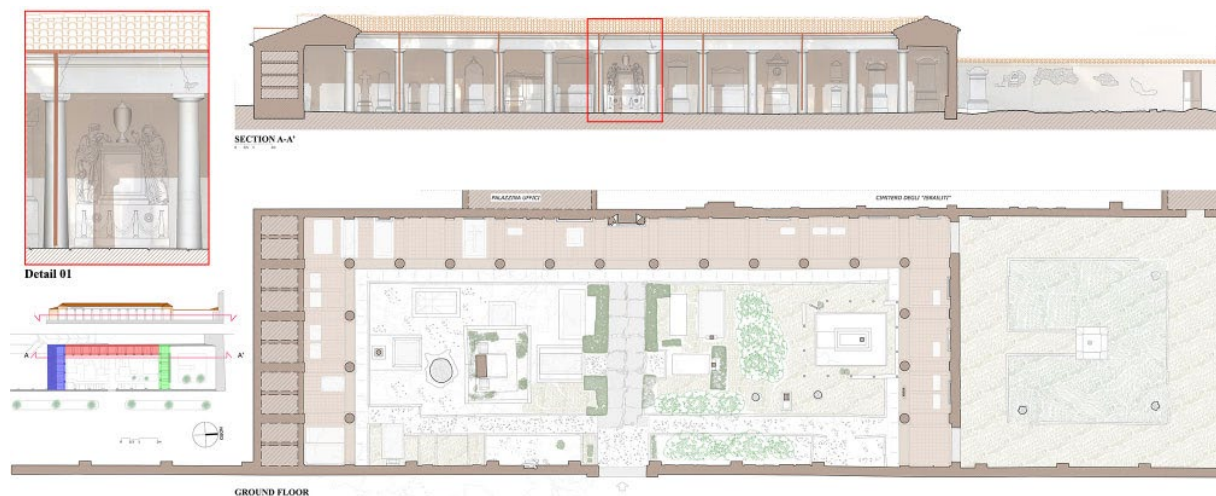


Fig. 7. Plan, elevation of one side and detail of the cloister, scale 1:50 and scale 1:20.

Following the representations, all lesions on the plan and elevations were mapped. During the crack mapping phase, some analyses were carried out, such as the twisting of the cloister dividing wall from the main avenue (Fig. 8). The cracks mapping is one of the crucial representation products that, together with careful photographic reportage, is fundamental for structural engineers to define the consolidation project, integrating this information with in situ tests.

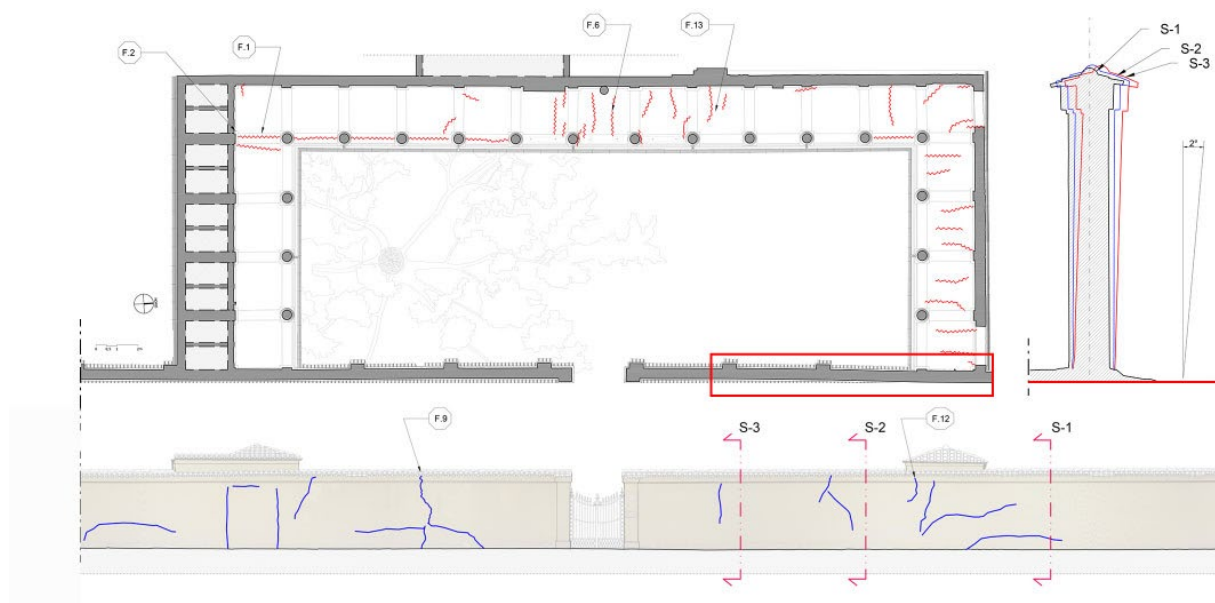


Fig. 8. Hypography of the floor plan and foreign elevation with mapped lesions. In detail, masonry torsion with out-of-plumb calculations.

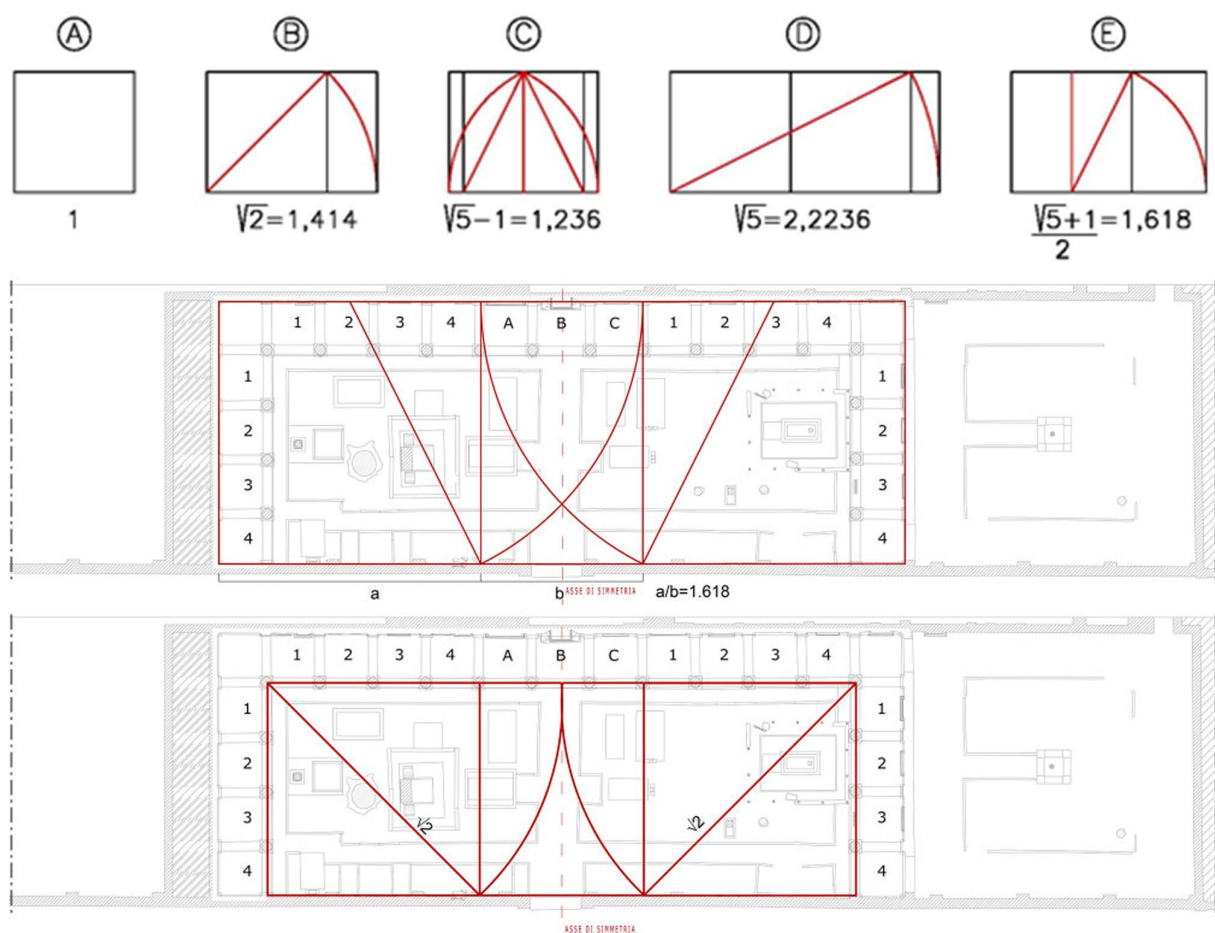


Fig. 9. Modular elements used for the proportion analysis and modular analysis in plan of the cloister.

A graphic analysis of the building forms presents in the structure followed this step. The architecture presents a unified geometric setting resulting from the use of the geometry of the square in its derived forms (Fig. 9). The extracted proportions (Fig. 9-10) are the results of rules and tracings to place open spaces, columns, and pilasters horizontally or vertically. The



human eye perceives these proportions as they constitute harmonic relationships between them. It has been the case since PHASE I, which saw the creation of the three central bays (a-b-a) fulcrum of the geometry of the Cloister, together with the north body.

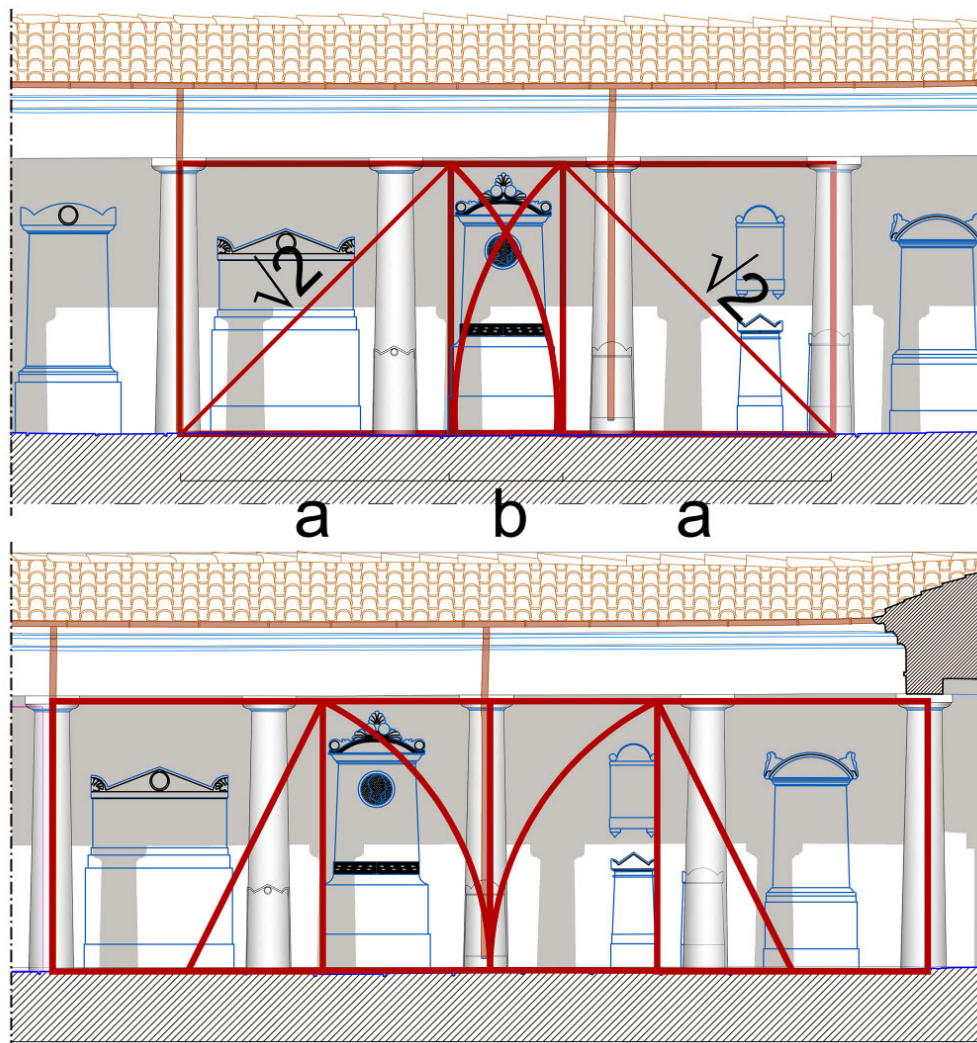


Fig. 10. Modular analysis in the central and lateral façade of the cloister.

## 5. Conclusions

The research deals with the topic of survey and representation of funerary architecture. In particular, the Cloister of the Evangelists within the Certosa of Bologna is explored. The study shows how this type of artifact contains a great wealth in historical, artistic, and sculptural terms, with a complex evolution. Using an integrated surveying process and the tools proper for representation allowed the construction of a fundamental knowledge model to understand this complexity better, building the basis for future interventions while defining good practices scalable to other similar environments within the Certosa area.

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