DIGITAL RECONSTRUCTION OF THE 19TH-CENTURY SANTA CATALINA INFIRMARY, AREQUIPA

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1. Introduction

The Monastery of Santa Catalina in Arequipa is one of the most emblematic urban and architectural ensembles in the southern Andean region and was inscribed on the UNESCO World Heritage List in 2000. Located within the historic center of the city, the monastery represents a fundamental reference for the study of female monastic life during the Viceroyalty of Peru. Numerous studies have examined the evolution of its architectural heritage, addressing its historical development, spatial organization, structural characteristics, and urban significance from the sixteenth to the nineteenth century [1-3].

Despite this extensive body of research, academic literature reveals a limited number of studies focused on the digital reconstruction of monastic spaces associated with labour, care, and community life, particularly those employing advanced documentation techniques combined with rigorous historiographical validation. This gap restricts a comprehensive understanding of spaces that have undergone functional transformation, adaptive reuse, or inadequate interventions, conditions that increasingly affect the legibility and long-term preservation of monastic heritage.

A paradigmatic case of such transformation is the space originally conceived as the convent infirmary, currently known as the Sala Zurbarán, located along Málaga Street within the Santa Catalina Monastery. In its present state, the infirmary functions as an exhibition gallery and tourist gift shop, uses that differ substantially from its original architectural, functional, and symbolic intent. Historically, the infirmary constituted a place of retreat and silence, dedicated to the care of infirm nuns and to their spiritual accompaniment during the final stages of life. As such, it synthesized the dimensions of physical care and eschatological contemplation within the monastic enclosure, integrating bodily fragility with the transcendent hope of eternal life.

The contemporary re-signification of this space has contributed to the gradual erosion of its original symbolic and functional meaning, underscoring the need for interpretative tools capable of recovering its architectural memory and spiritual significance. In this context, digitally validated reconstruction emerges as a methodological strategy that enables the critical recovery of historical configurations, spatial hierarchies, and devotional structures that are no longer legible within the building's material fabric.

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The present research aims to demonstrate how the digital reconstruction of the former convent infirmary of the Monastery of Santa Catalina constitutes an effective instrument for heritage preservation and interpretation. Through advanced methodologies of three-dimensional documentation and modeling, integrated within a structured workflow and supported by historical validation based on primary archival sources and international conservation standards, the study seeks to digitally reconstruct the original architectural, liturgical, and eschatological dimensions of this space. In doing so, it reveals the infirmary as a place of transition between earthly life, illness, death, and the hope of union with the divine. Figure 1 presents the monastic complex and the location of the infirmary, while Figure 2 shows an interior view of the space.

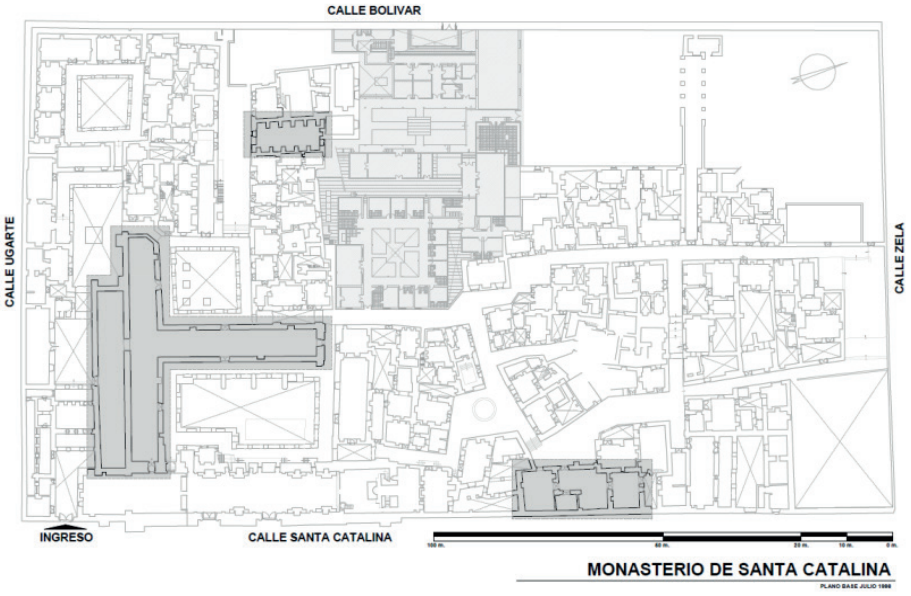

Figure 1. Location of the main community spaces on the base plan of Santa Catalina Monastery in Arequipa. (A) convent infirmary, (B) pinacoteca, (C) community kitchen.

Digital reconstruction, understood as a historically validated and analytically grounded process of virtual reconfiguration, is thus proposed as a technical and transdisciplinary instrument capable of making visible what has become obscured: the spiritual, communal, and symbolic meanings of a monastic space transformed by contemporary uses. In doing so, it contributes to broader discussions on the role of digital heritage in the conservation and interpretation of religious architecture.

Figure 2. Interior view of the convent infirmary, now Sala Zurbarán

2. State of the art

The digital restitution of the convent infirmary requires a methodological framework informed by international research on heritage documentation, digital reconstruction, and historical validation. In accordance with the three-stage workflow defined in the methodology, the state of the art is organized around three complementary thematic axes that correspond directly to: (i) digital documentation of heritage spaces, (ii) three-dimensional modeling for conservation and interpretation, and (iii) historical-architectural validation supported by international standards. This structure establishes continuity between existing research and the methodological approach adopted for the reconstruction of the Santa Catalina Monastery infirmary.

A. Digital Documentation of Heritage Spaces (Stage 1)

Accurate and non-invasive three-dimensional documentation constitutes the initial stage in processes of the digital restitution of architectural heritage. Remondino and El-Hakim [4] highlight that the combined use of optical sensors, 360° cameras, and SfM–

MVS algorithms enables the recording of complex geometries and current spatial conditions with high metric fidelity. Complementarily, D'Annibale et al. [5] and Martinenko et al. [6] demonstrate that the integration of terrestrial photogrammetry with panoramic imaging is particularly effective for documenting convent interiors and religious buildings, where access limitations and conservation requirements restrict invasive survey techniques.

In the context of traditional construction systems, the study by Mallafré-Balsells, Costa-Jover, and Coll-Pla [7] confirms the applicability of photogrammetric methodologies for the documentation of vernacular vaulted structures. These methodological principles are transferable to monastic complexes such as the Santa Catalina Monastery, characterized by heterogeneous construction phases and material configurations.

Latin American research further emphasizes the relevance of accessible documentation strategies in historically complex environments. Lynch et al. [8], working in the Hualfín Valley (Argentina), and Ortiz et al. [9], focusing on regional heritage contexts, illustrate the adaptability of photogrammetric approaches to sites with limited technical resources. At an information-management scale, Maietti and Zattini [10] explore the integration of HBIM and GIS platforms in Brazilian heritage contexts, demonstrating the potential of interoperable systems for organizing and managing heritage data.

A particularly relevant precedent is the study by Cuzziramos-Gutiérrez, Bernedo-Flores, Herrera-Bustinza, and Coll-Pla [11], which analyzed the microclimatic behavior of emblematic monastic cells within the Santa Catalina Monastery through non-invasive monitoring and diagnostic methodologies. This experience is especially pertinent to the community infirmary, where preservation constraints demand documentation strategies that avoid physical intervention while maintaining analytical rigor. Collectively, these studies inform Stage 1 of the workflow, centered on precise and non-invasive digital documentation.

B. Three-Dimensional Modeling for Heritage Protection and Interpretation (Stage 2)

The documentation techniques described above constitute the primary input for three-dimensional modeling and reconstruction processes applied to conventual architectural heritage. The combination of geometric representation with historical, material, and functional attributes enables the development of models that support both analysis and interpretation [12-13].

In this sense, 3D modeling functions as a tool for preservation and interpretation, allowing heritage assets to be recorded and communicated even when original material conditions have been altered. Komorowicz et al. [14] illustrate how neural-network-based approaches support reconstructions derived from historical photographic sources, while Cáceres-Criado and Romero [15] propose interactive virtual platforms that facilitate the validation and dissemination of reconstructed models.

Storeide [16] provides an overview of 3D modeling applications in cultural heritage, emphasizing their contribution to accessibility, documentation, and traceability. These contributions inform Stage 2 of the workflow, in which digital modeling supports the articulation of spatial configuration, functional organization, and interpretative content.

C. Historical-Architectural Validation and International Standards (Stage 3)

The credibility of digital reconstruction depends on systematic historical and architectural validation. Almagro-Gorbea et al. [17] and Cáceres-Criado and Romero [15] demonstrate that the use of primary documentary sources – such as inventories, pastoral visit records, building accounts, and historical plans – provides a reliable basis for the reconstruction of architectural heritage.

Within the Latin American context, the works of Rodríguez et al. [18] at the Convent of Santa Teresa in Cochabamba and Jaramillo and Gómez [19] in Santo Domingo, Quito, illustrate how digital survey data can be combined with archival documentation to achieve historically validated reconstructions. These studies highlight the importance of triangulating digital evidence with documentary sources to limit speculative interpretations.

This validation process is, moreover, framed by international conservation references, including the Venice Charter [20], the Seville Principles [21], ICOMOS and Getty Conservation Institute standards, and operational guidelines such as the *Manual de Documentación Gráfica del Patrimonio Histórico-Artístico* [22]. Together, these documents promote principles of traceability, transparency, metric fidelity, and replicability.

A particularly relevant normative reference is *Instructiones Fabricae et Supellectilis Ecclesiasticae* by Saint Charles Borromeo [23], which outlines architectural, sanitary, and spiritual criteria for ecclesiastical spaces, including convent infirmaries. Its relevance has been discussed by Giovannoni [24] and De Fusco [25], providing a normative framework for interpreting these spaces according to their original functional and symbolic intent.

The integration of these historiographical and normative references directly informs Stage 3 of the workflow, ensuring that the reconstructed digital model of the community infirmary at the Santa Catalina Monastery is historically validated and methodologically traceable. This alignment between the state of the art and the three-stage methodological workflow reinforces the coherence and international relevance of the proposed approach.

3. Method

The methodological framework adopted for the digital and historical reconstruction of the community infirmary of the Santa Catalina Monastery was structured as a sequential and traceable workflow, articulated in three complementary and interdependent stages, as shown in Figure 3. These stages include:

1. Three-dimensional data acquisition and documentation,
2. Digital modeling and geometric reconstruction,
3. Historical, architectural, and symbolic validation.

This structured workflow was conceived in accordance with international heritage documentation and reconstruction standards (ICOMOS, Seville Principles, London Charter, CIPA), ensuring metric reliability, historical verifiability, and interpretative transparency throughout the process.

The methodological innovation of the study does not lie in the individual technologies employed – widely consolidated in heritage documentation – but rather in their integrated application within a historically validated interpretative framework.

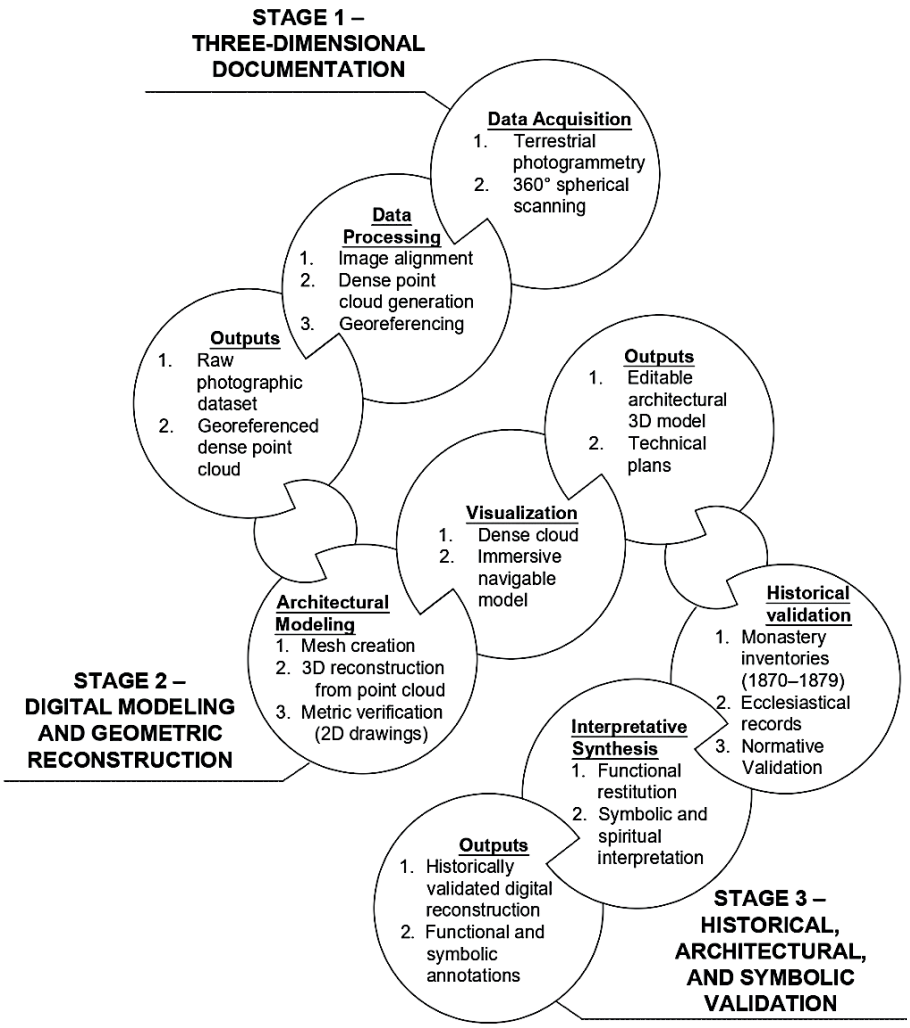

Figure 3. Sequential methodological workflow applied to the digital and historical reconstruction of the 19th-century community infirmary of the Santa Catalina Monastery.

Stage 1: Three-Dimensional Documentation and Data Acquisition

The first stage consisted of the comprehensive three-dimensional documentation of the community infirmary dormitory, conducted in May 2025. The survey strategy combined terrestrial photogrammetry and 360° spherical scanning, selected for their complementary strengths in heritage contexts characterized by spatial complexity and later functional transformations, as shown in Figure 4.

Figure 4. 360° spherical camera positioned at one of the scanning stations inside the community infirmary dormitory, illustrating the data acquisition setup used during the three-dimensional documentation process.

The choice of these technologies was motivated by:

- the need for metric precision (terrestrial photogrammetry),
- the requirement for immersive spatial comprehension and documentation of current museographic alterations (360° scanning),
- the non-invasive nature of both methods, suitable for an active heritage site.

A total of 15 scanning stations were distributed throughout the space at intervals of 1.20–1.50 m, maintaining an average distance of 1.80 m from the walls. Spherical images were captured using a Ricoh Theta X mounted on a 1.60 m tripod, while 248 high-resolution photographs were taken with a Canon EOS R50 to ensure adequate texture coverage and geometric overlap (80–90%) for photogrammetric processing.

The acquired data were processed in Agisoft Metashape, generating a dense,

georeferenced point cloud that served as the geometric basis for subsequent modeling phases. At the same time, an immersive visualization of the space in its current condition was developed using Matterport, enabling virtual inspection and analysis of the altered spatial configuration adapted for exhibition and commercial use.

The combined use of photogrammetry and spherical scanning proved particularly effective in documenting a space whose original function (spiritual retreat and medical care) has been substantially modified.

This combination of technologies has proven particularly effective in heritage contexts such as Santa Catalina Monastery where spaces have undergone significant transformations. The community infirmary, originally conceived as an area for spiritual retreat and care, comprising the dormitory, guard cell, treatment room, dispensary, and oratory, has now been repurposed as an exhibition hall and souvenir shop.

The technical characteristics of the equipment employed are shown in Table 1.

Table 1. Technical summary of the equipment used

Characteristic	***Ricoh Theta X (360° Spherical Camera)***	***Canon EOS R50 (Terrestrial Photogrammetry)***
Type of capture	*Spherical image / 360° panoramic scan*	*High-resolution terrestrial photography (APS-C sensor, mirrorless camera)*
Still image resolution	*Up to 11,008 × 5,504 pixels (11K)*	*24.2 megapixels (approx. 6,000 × 4,000 px)*
Video / frame rate	*5,760 × 2,880 px at 30 fps*	*4K UHD at 30 fps (oversampled); full HD up to 120 fps*
Sensor type / size	*Dual integrated CMOS sensors*	*CMOS APS-C (22.3 mm × 14.9 mm)*
Capture format	*JPEG / HDR / RAW*	*RAW (CR3) + JPEG*
Mount / capture height	*Tripod at 1.60 m*	*Fixed tripod (no remote trigger)*
Distance between stations	*1.20–1.50 m*	*Not applicable (photogrammetry with 80–90% overlap)*
Average distance from walls	*1.80 m*	*Variable, depending on texture coverage*
ISO / sensitivity	*Automatic, adapted to environment*	*ISO 100–32,000 (expandable)*
Focusing system	*Not applicable (fixed spherical image)*	*Dual Pixel CMOS AF II, 651 focus zones*
Use in the project	*Immersive visualization prior to modeling*	*Capture of architectural details and textures for alignment and detailed photogrammetry*

Stage 2: Digital Modeling and Geometric Reconstruction

The second stage focused on the construction of a metric, editable, and interoperable 3D model, based on the dense point cloud generated during Stage 1.

The modeling strategy was articulated across multiple software platforms, each selected for a specific technical role within the workflow:

- Agisoft Metashape Pro for photogrammetric processing, dense cloud generation, and textured mesh creation;
- SketchUp Pro 2023 for architectural 3D modeling, selected for its compatibility with point clouds and its efficiency in reconstructing complex interior geometries;

- AutoCAD 2024 for dimensional verification, 2D technical drawings, and cross-checking metric accuracy;
- Matterport for immersive visualization and spatial navigation (Figure 5).

This multi-software approach ensured compliance with international standards such as the Seville Principles [21], the *Manual de Documentación Gráfica del Patrimonio Histórico-Artístico* [22], and CIPA Heritage Documentation specifications [26], allowing full traceability between raw data, processed models, and interpretative outputs.

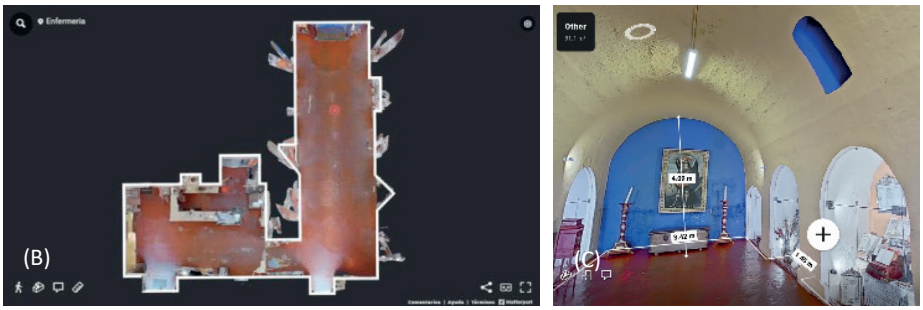

Figure 5. Integration of the 3D model within the Matterport platform. (A) Isometric view of the model; (B) plan view of the model; (C) interior view of the model with measurements.

To reinforce historical consistency, original architectural drawings preserved in the Santa Catalina Monastery *Planoteca*, notably the 1964 blueprints and the 1996 consolidated plan, were consulted to verify proportions, wall thicknesses, and spatial organization. This phase was further strengthened through validation sessions conducted with a specialist historian, who provided documentary sources and functional interpretations derived from conventual records.

The software tools employed and their respective roles are detailed in Table 2.

Table 2. Software used for 3D modelling and visualization

Software	***Main Function***	***Version Used***	***Key Technical Features***	***Supported Formats***	***Compatibility***
Agisoft Metashape Pro	*Photogrammetric processing and point cloud generation*	*v2.0*	*– SfM and MVS algorithms – Dense point cloud – 3D mesh and texturing – Georeferencing – Export compatible with GIS/BIM*	*.OBJ, .PLY, .LAS, .XYZ, .TIFF, .JPG, .KML*	*Windows, macOS, Linux*
SketchUp Pro	*Architectural 3D modeling*	*2023*	*– User-friendly interface – Point cloud compatibility – Visualization plugins – Export to other CAD formats*	*.SKP, .OBJ, .3DS, .DAE, .STL, .DXF, .DWG*	*Windows, macOS*
AutoCAD	*Technical drawing and 2D/3D modeling*	*2024*	*– Millimetric precision – Annotation and comparison tools – ISO and CAD standard compliance*	*.DWG, .DXF, .DWF, .PDF, .DGN*	*Windows, macOS*
Matterport	*Immersive visualization and web navigation*	*2025 (web-based)*	*– Interactive 360° exploration – Direct measurement in virtual environment – Integration with OBJ models*	*.OBJ, .E57, .XYZ, online cloud*	*Web, iOS, Android*

Stage 3: Historical, Architectural, and Symbolic Validation

The third stage consisted of a rigorous historical and architectural validation process, aimed at ensuring that the digital reconstruction was not merely geometrically accurate, but also historically grounded and symbolically coherent.

Primary sources from the Santa Catalina Monastery Archive [27] and the Archiepiscopal Archive of Arequipa [28] were systematically analyzed, including building accounts, pastoral visit records, and convent inventories dated between 1870 and 1879. This documentary corpus enabled the reconstruction of spatial functions, devotional elements, and patterns of use, while preventing speculative or anachronistic interpretations.

Normative validation was carried out through a critical reading of *Instructiones Fabricae et Supellectilis Ecclesiasticae* by Saint Charles Borromeo [23], a foundational post-Tridentine treatise regulating ecclesiastical and conventual architecture. Although

conceived in the European context, Borromean principles were interpreted in light of local adaptations observed in Arequipa, particularly regarding climate, materials (volcanic sillar stone), and Andean spatial practices.

The cross-analysis between normative prescriptions and archival evidence revealed both structural continuities and context-specific adaptations, such as:

- the stable presence of a Marian-Christological altar,
- the introduction of curtained alcoves for privacy,
- the differentiation between treatment and convalescence spaces.

This historical evolution is synthesized in Table 3, while Table 4 presents a comparative technical analysis between Borromean norms and documented practices at Santa Catalina.

Table 3. Historical evolution of the convent infirmary (1870–1879)

Year	***Main Spaces***	***Devotional Elements***	***Relevant Spatial and Functional Changes***
1870	*Main hall with 8 platforms and 7 cots; secondary room with 3 cupboards; pharmacy; kitchen*	*Not specified*	*First detailed record. The space remained basic, focused on lodging for the sick and providing essential services.*
1872	*Main hall; room with cupboards; pharmacy; small room; kitchen; refectory*	*Altar to the Holy Christ and Our Lady of the Rosary*	*The refectory was explicitly added. Integration of liturgical and devotional dimensions into physical treatment.*
1877	*Main hall with 8 cubicles with curtains; pharmacy; room for priest; small room*	*Altar to the Holy Christ and the Virgin of the Rosary*	*Increased privacy for the sick, inclusion of space for spiritual assistance, and gradual modernization of communal care.*
1879	*Main hall with 9 platforms, 8 cots, and 8 bunk beds; convalescence room; priest's room; pharmacy; small room*	*Altar to the Holy Christ and the Virgin of the Rosary*	*Consolidation of spatial organization. Addition of the convalescence room reflects improved medical-assistance practices and differentiation of care and recovery areas.*

Methodological synthesis

The adopted workflow integrates terrestrial photogrammetry, 360° spherical scanning, and multi-platform 3D modeling within a sequential and verifiable framework tailored to the spatial scale and operational conditions of the site. Alternative approaches, including terrestrial laser scanning (TLS), LiDAR-based surveys, HBIM environments, and structured-light scanning, were considered but not implemented due to their higher acquisition and operational costs, the need for specialized equipment and trained personnel, longer on-site survey times, and limited flexibility in confined interior spaces subject to conservation and access constraints. Similarly, advanced modeling and management platforms requiring high-cost licenses or extensive parameterization were not applied in order to maintain methodological accessibility, transparency, and replicability. The adopted workflow presents inherent limitations related to data density in low-texture areas and interoperability between software environments; however, these constraints remain within acceptable margins for architectural-scale analysis. The innovative contribution of the study lies in the integrated articulation of digital documentation, historical sources, and normative analysis, rather than in the isolated deployment of individual technologies.

Table 4. Comparative technical analysis: Borromean norms vs. Santa Catalina Monastery inventories

Category	***Borromean Prescription (1577)***	***Historical Evidence in the Santa Catalina Monastery Archive (1870–1879)***	***Detected Adaptations***
Location	*Healthy site, distant from the cloister, and near the auditorium*	*Located adjacent to an interior courtyard, with relative functional independence*	*The criterion of semi-isolation was maintained, adapted to the urban topography of Arequipa*
Functional Organization	*Refectory, kitchen, pantry, pharmacy, woodshed, lower and upper cells, orchard*	*Main hall with beds and alcoves, pharmacy, kitchen, room for episcopal use, convalescence room*	*Woodshed and orchard omitted from inventories, though confirmed through historical plans*
Privacy Spaces	*Cells with beds and sanitary facilities, including individual stoves*	*Alcoves with curtains, separate rooms for rest and recovery*	*Incorporation of architectural solutions for privacy and functional differentiation in the 19th century*
Spiritual Dimension	*Not explicitly included; focused on discipline*	*Altar to the Holy Christ and the Virgin of the Rosary, stably recorded since 1872*	*Affirmation of spirituality as an essential component of care for sick nuns*
Spiritual Assistance	*General recommendation for episcopal supervision*	*Room for episcopal use included in 1877 and 1879, intended for confessors and sacramental administration*	*Strengthening of religious and sacramental accompaniment during the convalescence process*
Stages of Care	*No clear differentiation*	*Distinction between active patients and convalescents in the 1879 inventory*	*Application of modern healthcare criteria: separation between treatment and recovery phases*

Comparative positioning within international literature

At the level of Stage 1: Three-dimensional documentation; numerous international studies have applied terrestrial photogrammetry, laser scanning, or hybrid survey techniques to religious and monastic architecture, particularly churches, abbeys, and cloisters. Works such as Remondino et al. [29] and González-Aguilera et al. [30] demonstrate high levels of geometric accuracy in the digital documentation of historic churches, while Bruno et al. [31] extend these approaches through HBIM-oriented survey pipelines for religious complexes. However, these studies primarily emphasize metric acquisition and structural representation, with limited consideration of functional transformation or symbolic meaning associated with specific monastic spaces such as infirmaries.

In Stage 2: Digital modeling and geometric reconstruction; research on monastic and ecclesiastical heritage has largely focused on formal restitution, visualization, and

data enrichment. Apollonio, Gaiani and Sun [32] and Guidi, Russo and Angheleddu [33] provide methodological frameworks for 3D reconstruction of religious architecture, emphasizing geometric consistency and visual communication. While these contributions establish robust modeling standards, they rarely incorporate documentary inventories or liturgical prescriptions as active parameters guiding the reconstruction process. In contrast, the present study integrates architectural modeling with historical plans and conventual documentation, allowing the digital model to function as both a geometric and interpretative construct.

At Stage 3: Historical, architectural, and symbolic validation, and existing literature show a significant gap. Although several studies acknowledge the historical value of religious buildings, validation is generally limited to stylistic or chronological attribution [34]. Normative ecclesiastical texts and monastic inventories are seldom employed as structured validation tools within digital workflows. The present research differs by systematically triangulating archival inventories, post-Tridentine normative prescriptions (Borromeo) and digital survey data to reconstruct not only the spatial configuration of the infirmary but also its functional, devotional, and eschatological dimensions. This approach positions the digital model as a historically verified interpretative framework rather than a purely representational output.

Through this three-stage comparative perspective, the study strengthens its positioning within the international literature by addressing a largely unexplored typology – the monastic infirmary – and by demonstrating how digital heritage methodologies can recover architectural form, historical function, and spiritual meaning through an integrated and replicable workflow.

4. Results

A. Technical Results

According to primary archival sources and post-Tridentine normative frameworks, particularly those established by Saint Charles Borromeo, the convent infirmary functioned as an articulated system supported by complementary spaces essential to its operation. Within this complex, the space digitally reconstructed in this study corresponds to the infirmary dormitory (81.0 m²), originally conceived as the main area for the care and rest of sick nuns. The associated support spaces documented in historical sources, including a pharmacy, a convalescence room, a liturgical room, a refectory–kitchen, and a small service courtyard with a well, have undergone substantial alterations over time and are currently excluded from the tourist itinerary (Figure 6).

The digital survey of the infirmary dormitory produced high-precision metric documentation with an estimated resolution of 0.45 mm per pixel. This level of detail was achieved through the combined use of 248 terrestrial photogrammetry photographs and 15 spherical images captured with a 360° camera, ensuring comprehensive spatial coverage and an accurate three-dimensional representation of the space. The resulting dense point cloud, comprising approximately 950,000 points, enabled the generation of spatial models with a high degree of geometric fidelity, supporting the identification of architectural, ornamental, and furnishing elements and forming the basis for interior views, three-dimensional sections, and virtual reconstructions (Figure 7).

The modeled area of the dormitory is characterized by a unified spatial composition without major internal subdivisions. Historical validation confirmed the preservation of key original structural features, including a continuous vaulted ceiling, lateral niches embedded within thick ignimbrite walls, and a main entrance oriented toward Málaga

Street. Among the most significant morphological findings, ten vaulted niches were identified, each incorporating a curtain system, a small bench, and a built-in bed, together with four central wooden tables aligned along the main axis, likely associated with care-related or ritual activities.

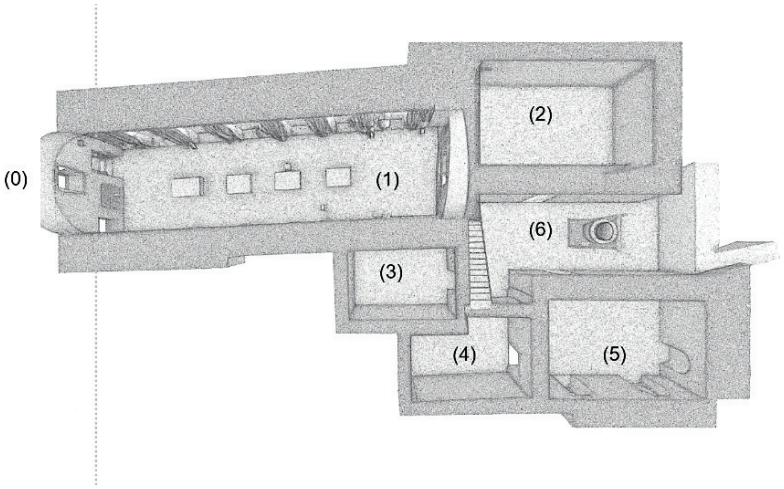

Figure 6. Validated 3D model, view of the ensemble with access to ancillary spaces. (0) Málaga Street; (1) infirmary dormitory – 81.0 m²; (2) pharmacy; (3) convalescence room; (4) liturgical room; (5) refectory–kitchen; (6) small service courtyard with well.

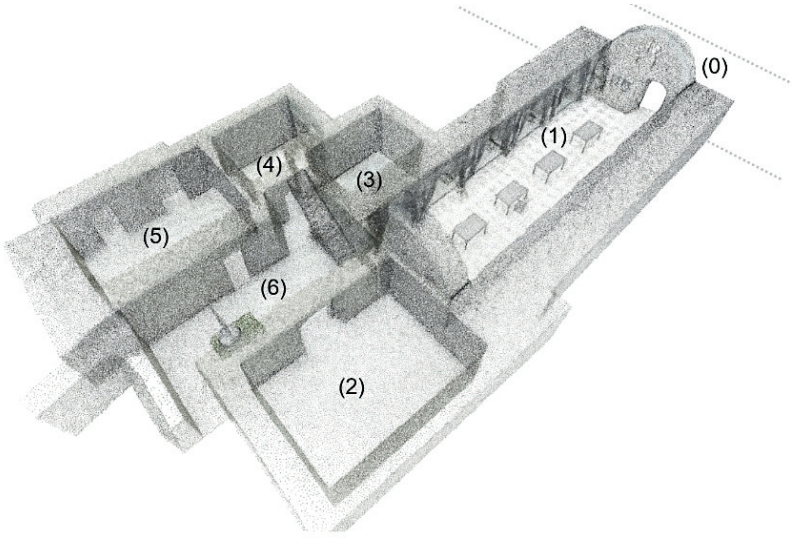

Figure 7. Validated 3D model, aerial overview views. (0) Málaga Street; (1) infirmary dormitory – 81.0 m²; (2) Pharmacy; (3) convalescence room; (4) liturgical room; (5) refectory–kitchen; (6) small service courtyard with a well.

Another relevant finding concerns the rear wall of the dormitory, where a painting of an archangel is currently displayed. As illustrated in Figures 8 and 9, digital and documentary analysis confirmed that this area originally housed a central altar and a doorway connecting to an interior courtyard and a group of auxiliary spaces that are currently inaccessible to visitors as they belong to the contemporary cloistered area of the monastery. In addition, the high window facing Málaga Street was verified as an original architectural element, playing a fundamental role in the ventilation and illumination of the space.

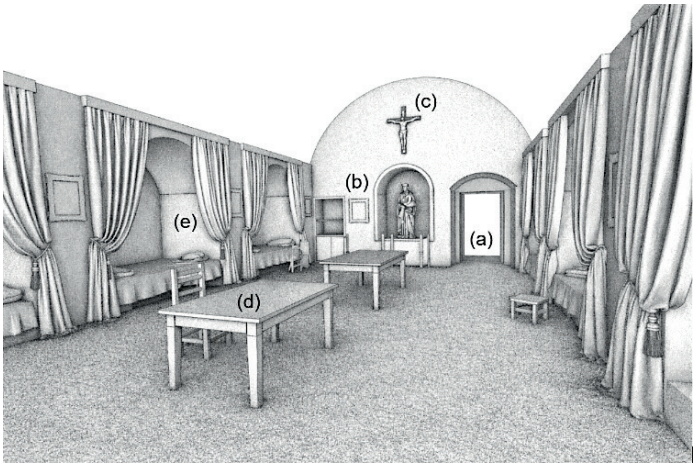

Figure 8. Validated 3D model, view toward the rear wall. (a) Door facing the small service courtyard with a well, currently closed; (b) altar; (c) wall-mounted crucifix; (d) wooden table; (e) individual niche with curtain.

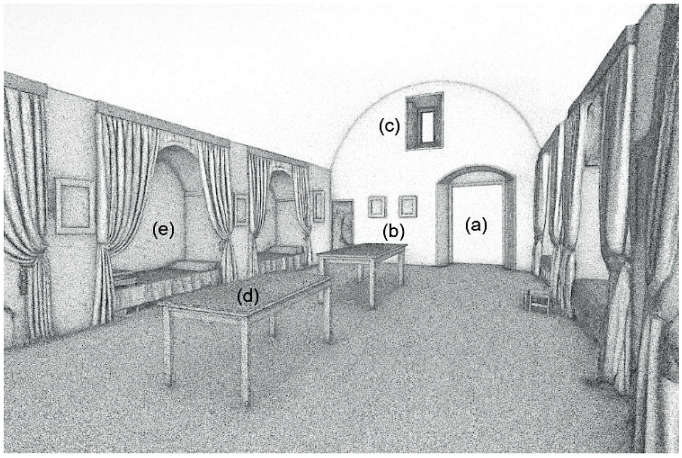

Figure 9. Validated 3D model, view toward the wall adjoining Málaga Street. (a) Door facing Málaga Street; (b) paintings of saints; (c) high window; (d) wooden table; (e) individual niche with curtain.

A comparison between the reconstructed model and 19th-century historical plans revealed substantial transformations within the infirmary complex. These changes include modifications in the connections between spaces, particularly in the rear area of the dormitory and in its articulation with rooms currently used as a souvenir shop. The analysis confirmed that such connections did not exist in the original spatial configuration.

The validation of these technical results was conducted in close coordination with the historian involved in the research. Her documentary investigation enabled the identification of architectural and functional elements that had been obscured by contemporary transformations. This collaboration proved essential for digitally reconstructing otherwise invisible features, restoring the original spatial logic of the infirmary and recovering its spiritual and functional significance.

Finally, the generated models are compatible with interactive platforms such as Matterport and Sketchfab, allowing virtual exploration of the infirmary dormitory by both specialists and the general public. These three-dimensional visualizations constitute effective tools for heritage dissemination, conservation support, and educational purposes. A summary of the technical results is presented in Table 5.

Table 5. Summary of technical results

Parameter	***Value***
Metric precision	*0.45 mm/pixel*
Number of photos (photogrammetry)	*248*
Number of photos (360°)	*15*
Point cloud density (dense cloud)	*950,000*
Number of identified niches	*10*
Height of entrance opening	*3.25 m*
Presence of altar and niche	*Confirmed*
Number of central tables	*4*
Original window facing Málaga Street	*Confirmed (1 unit)*

B. Symbolic, Semiotic, and Interpretive Results

Beyond quantifiable technical data, the analysis of the community infirmary dormitory revealed symbolic dimensions deeply embedded in conventual spirituality. Conceived as a space for the care of sick nuns during the final stages of their life, the dormitory functioned as a threshold between active monastic life and contemplative preparation for death, reinforcing the eschatological character inherent in monastic architecture.

Each vaulted niche, equipped with curtains and minimal furnishings, operated as an individualized symbolic cell within a collective setting, expressing the tension between personal retreat and communal prayer. This spatial order enabled privacy and care while sustaining the shared rhythm of spiritual accompaniment.

The altar, reconstructed through the cross-analysis of historical plans and archival testimonies, was located at the rear of the space and dedicated to the Holy Christ and Our Lady of the Rosary. As shown in Figure 10, it served as the devotional and symbolic axis of the dormitory, articulating rituals of spiritual assistance within an architectural setting oriented toward consolation and hope, together with furnishings, niches, and access to a small service courtyard. Figure 11 highlights the relationship with Málaga

Street, including furniture details and the high window that ensured general ventilation and illumination. Wall paintings of saints documented in 19th-century convent chronicles, including Saint Teresa of Ávila, Saint John of the Cross, and Saint Rose of Lima, reinforced the role of visual catechesis within cloistered life.

Figure 10. Detailed historical reconstruction of the infirmary dormitory, showing the altar, furnishings, niches and access to a small service courtyard.

Figure 11. Detailed historical reconstruction of the space, showing the exit to Málaga Street, furniture details, and the high window providing general ventilation and illumination for the infirmary dormitory.

The digital reconstruction also clarified the original spatial hierarchy of the infirmary, emphasizing the ordered relationship between altar, curtained beds, central tables, directed lighting, and structured niches. This configuration was not governed solely by medical or hygienic criteria but was structured according to a symbolic logic in which architecture actively contributed to shaping the spiritual interpretation of illness, suffering, death, and salvation.

By making the original mystical configuration of the infirmary visible, the reconstruction demonstrates how architectural design participated in articulating the monastic understanding of suffering, the proximity of death, and the hope of resurrection. These symbolic values, largely obscured by recent interventions, were recovered through historical validation, enabling a more comprehensive interpretation of the conventual heritage and facilitating its integration into interactive digital environments. The principal symbolic and interpretive results are summarized in Table 6.

Table 6. Summary of symbolic, semiotic, and interpretive results

Dimension	***Description***	***Documentary or Visual Evidence***	***Symbolic and Semiotic Interpretation***
Spiritual Function of the Space	*Dormitory as a place of transition between active life and eternal contemplation*	*Historiographic validation / digital reconstruction*	*Eschatological space reinforcing the notion of a "good death" and passage to eternal life*
Niche–Cell	*Ten curtained niches symbolizing individual cells within a collective setting*	*Reconstructed image, 1877–1879 inventories*	*Representation of balance between contemplative solitude and communal prayer life*
Altar at the Rear of the Dormitory	*Altar dedicated to the Holy Christ and Our Lady of the Rosary*	*1872 and 1879 inventories, virtual reconstruction*	*Devotional center and axial core of the space; sacralization of care for ~~the~~ sick nuns*
Paintings of Saints on the Walls	*Representations of Saint Teresa, Saint John of the Cross, Saint Rose of Lima, among others*	*Descriptions in 18th-century convent chronicles*	*Visual models of virtue, resignation, and spirituality in the face of suffering*
Hierarchical Spatial Organization	*Arrangement of niches, altar, central table, pharmacy, etc.*	*Digital reconstruction and comparison with historical plans*	*Disciplined space structured under Tridentine logic adapted to the local context*
Presence of the Priest	*Room for priest documented*	*1877 inventory*	*Assurance of spiritual assistance and administration of the sacraments*
Convalescence Room	*Additional area for nuns in recovery*	*1879 inventory*	*Medical-assistive evolution of the space, differentiating treatment and recovery phases*
Absence of Orchard and Woodshed	*Not documented but confirmed in plans*	*Comparison with Borromean prescriptions*	*Functional adaptation to the urban context of Arequipa*
Original Configuration vs. Contemporary Use	*Transformation of the space into a shop; removal of the altar and wall alterations*	*Comparison between 3D models and current use*	*Loss of original meanings; need for symbolic restitution through digital reconstruction*

5. Discussion

The three-dimensional reconstruction of the community infirmary dormitory at the Santa Catalina Monastery in Arequipa demonstrates the effectiveness of an integrated methodological approach that combines advanced digital technologies with rigorous historical and normative validation. The workflow, articulated in three sequential stages – digital documentation, geometric reconstruction, and historical-symbolic validation – enabled the development of a digital model that is both metrically reliable and historiographically grounded. This methodological structure aligns with international experiences in the digital documentation of religious and monastic heritage, while addressing gaps identified in comparable studies, particularly regarding the interpretation of care-related and liminal monastic spaces.

The integration of terrestrial photogrammetry, 360° spherical scanning, multi-platform 3D modeling, and interactive visualization tools, such as Matterport, were systematically coordinated with archival sources and canonical regulations, notably *Instructiones Fabricae et Supellectilis Ecclesiasticae* by Saint Charles Borromeo [23]. The resulting model adheres to the conservation principles promoted by ICOMOS [35], the CIPA Heritage Documentation recommendations [36], and the London Charter for the Computer-based Visualization of Cultural Heritage [37], confirming its consistency with internationally recognized standards for digital heritage projects.

Beyond its high metric resolution, reaching 0.45 mm per pixel and generating a dense point cloud of nearly one million points, the model's scientific value lies in its validated 0historical coherence. Each architectural and functional component was systematically cross-referenced with nineteenth-century convent inventories, building accounts, and pastoral visitation records, under the supervision of a specialist historian. Within this framework, digital restitution is understood as a historically grounded process of digitally reconstructing lost or transformed architectural configurations and constitutes the methodological foundation of the study. This approach supports the position articulated by Fregonese [38], who argues that digital restitution models can function as scientific heritage documents when embedded within a transparent and traceable historiographical framework.

From an interpretive perspective, the spatial analysis confirms that the infirmary dormitory was not conceived merely as an assistive or medical environment, but as a symbolic architectural device integrating bodily care with the eschatological dimension of monastic life. The axial placement of the altar, the sequence of curtained niches, the persistence of devotional imagery, and the articulation between shared and individual spaces reveal a spatial order imbued with theological meaning. This reading is consistent with the interpretative frameworks proposed by Eco [39] and Panofsky [40], who emphasize that sacred architecture embodies structured systems of thought and belief rather than neutral functional arrangements.

In this sense, the digital reconstruction transcends the reproduction of form and enables the recovery of symbolic layers that have been progressively neutralized by contemporary interventions. The transformation of the infirmary dormitory into a shop and museographic space – although respectful of the building's material integrity – has diluted fundamental aspects of its original meaning, including the liturgical centrality of the altar and the hierarchical spatial logic of care and contemplation. This situation echoes the concerns expressed by Feilden [41] and Avrami, Mason, and de la Torre [42], who warn that musealization processes, when not accompanied by critical interpretation, may result in conservation strategies that privilege appearance over meaning.

Within this context, digital reconstruction operates as a virtual restitution mechanism

and interpretive mediation tool, capable of reactivating forgotten readings, testing historically informed hypotheses, and supporting conservation strategies that integrate material preservation with symbolic recovery. The reconstructed model satisfies the three levels of utility identified by Fregonese [38]:

(i) Documentary, as a precise, traceable, and verifiable record;
(ii) Analytical, enabling comparison with archival documentation and normative prescriptions; and
(iii) Communicative, facilitating dissemination and understanding among both specialist and non-specialist audiences.

An additional contribution of this workflow lies in its replicability and transdisciplinary potential. The structured three-stage methodology can be adapted to other monastic or religious complexes facing similar challenges of transformation and loss of meaning. Moreover, the digital model that has been generated can be translated into physical three-dimensional prints, allowing the production of scaled maquettes for educational and interpretive purposes. Such physical models offer opportunities for transdisciplinary engagement, serving as tactile and visual tools for heritage education, guided tours, and inclusive learning experiences for visitors to the monastery. In this way, digital heritage extends beyond virtual visualization, fostering new forms of interaction between architecture, history, technology, and public outreach.

Ultimately, the digitally restituted infirmary dormitory emerges as a transdisciplinary heritage object at the intersection of architecture, theology, history, and digital technology. This experience confirms that three-dimensional documentation is not merely a technical operation, but a critical act of heritage interpretation – one capable of preserving architectural form while restoring the symbolic and spiritual depth of a space whose original meaning had been obscured by contemporary use.

6. Conclusions

This research demonstrates the relevance and effectiveness of an integrated digital and historical methodology applied to the documentation, reconstruction, and interpretation of monastic architectural heritage. Focusing on the infirmary dormitory of the Santa Catalina Monastery in Arequipa – a space selected for its high degree of morphological preservation within a context of widespread contemporary transformations – the study confirms the potential of digital heritage tools to recover both architectural form and historical meaning.

The developed and applied three-stage workflow – comprising three-dimensional documentation, digital modeling and geometric reconstruction, and historical-symbolic validation – proved to be methodologically coherent, replicable, and adaptable to other religious or monastic contexts. The combination of terrestrial photogrammetry, 360° spherical scanning, and multi-platform modeling generated a dense point cloud of nearly one million points, with a resolution of 0.45 mm per pixel, ensuring a high level of metric fidelity. This precision enabled the identification and restitution of key spatial elements, including the axial organization of the dormitory, the sequence of curtained niches, and the original position of the altar, all of which are essential for understanding the functional and symbolic logic of monastic infirmary spaces.

Historical and semiotic validation, based on primary archival sources – such as inventories from 1870–1879, monastic and archiepiscopal records – and normative texts including *Instructiones Fabricae et Supellectilis Ecclesiasticae* by Saint Charles Borromeo [23], confirmed the infirmary's dual role as a place of bodily care and spiritual

preparation. The space emerges as an architectural device in which medical assistance, monastic discipline, and eschatological meaning converge, articulated through liturgical focal points, devotional imagery, and a carefully structured spatial hierarchy.

From a heritage conservation perspective, the resulting 3D model functions as an integrated tool with documentary, analytical, and communicative value. Beyond visualization, it constitutes a historically validated interpretative framework capable of supporting informed conservation strategies, critical museographic approaches, and preventive management policies. The study reinforces the idea that digital reconstruction, when grounded in archival evidence and international conservation standards, can act as a form of virtual reconstruction that complements material preservation while addressing the loss of symbolic and functional meaning caused by adaptive reuse.

A significant applied outcome of this research is the production of a physical three-dimensional printed model of the 19th-century infirmary, derived directly from the validated digital reconstruction. This physical model, conceived as a didactic and interpretative artifact, will be donated to the Santa Catalina Monastery complex for permanent exhibition, reinforcing the link between academic research, heritage dissemination, and public engagement. The physical model offers an accessible medium for communicating complex spatial, historical, and symbolic information to non-specialist audiences, including tourists, students, and educators, thereby extending the impact of digital heritage beyond virtual environments.

In conclusion, this study demonstrates that three-dimensional documentation and reconstruction operate as interpretative processes within heritage research. Through the integration of architecture, history, technology, and theology in a structured and replicable workflow, the research advances digital heritage methodologies and supports the preservation of the architectural, spiritual, cultural, and symbolic dimensions of monastic heritage.

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Summary

This study presents the digital and historical reconstruction of the 18th-century community infirmary dormitory at Santa Catalina Monastery in Arequipa, Peru. By integrating advanced digital documentation technologies – such as terrestrial photogrammetry, 360° spherical scanning, and parametric 3D modeling – with rigorous historical and canonical validation, this research proposes a replicable methodological model for the documentation and interpretation of monastic heritage. The study highlights the interdisciplinary convergence of architecture, history, theology, and technology, where the digital model functions not only as a metric record but also as a spiritual and symbolic restitution of a space that once mediated between physical care and eschatological contemplation.

Riassunto

Questo studio presenta la ricostruzione digitale e storica del dormitorio dell'infermeria comunitaria del XVIII secolo nel Monastero di Santa Catalina ad Arequipa, in Perù, realizzata attraverso l'integrazione di tecnologie avanzate di documentazione digitale – come la fotogrammetria terrestre, la scansione sferica a 360° e la modellazione parametrica 3D – con una rigorosa validazione storica e canonica. La ricerca propone un modello metodologico replicabile per la documentazione e l'interpretazione del patrimonio monastico, evidenziando la convergenza interdisciplinare tra architettura, storia, teologia e tecnologia. Il modello digitale risultante non solo costituisce un registro metrico preciso, ma rappresenta anche una restituzione spirituale e simbolica di uno spazio che un tempo mediava tra la cura fisica e la contemplazione escatologica.