edited by

SANDRO PARRINELLO

FRANCESCA PICCHIO

Architectures along James I itinerary in the Valencian Province

FIRENZE UNIVERSITY PRESS

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Persistent forms in Valencia Cathedral. © Sandro Parrinello

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Side page, Fig. 01
Multisource Database
Integrated point cloud of St. Mary Church in the Monastery of Simat de la Valldigna.

Operations related to the structuring of 3D databases applied to the study and documentation of architectural heritage today rely on well-established methodological practices that use continuously evolving instrumentation[1]. The implementation and management of databases are not limited to defining the structure of a vast data system within a more or less complex context. More specifically, it involves a cognitive filter through which it becomes possible to read and interpret the architecture of objects and space[2].

In the research for expressive languages applicable to the Cultural Route in a broader sense, the graphic product emerges as an expressive vehicle for information, redefining the relationship between "sign and meaning" in the digital dimension[3]. Technological progress and the push toward digitisation have shifted all forms of documentation systems within the cultural heritage field toward the creation of digital platforms[4]. These interfaces gather descriptive tools useful for the development of new methodological protocols applicable to the management of heterogeneous information. Similarly, the science of architectural surveying, in all its variations, from the survey of historical buildings to the urban landscape, has embarked on an innovative path aimed at creating digital environments structured as point clouds and three-dimensional models, conceived as databases of spatial coordinates. This transformation from spatial data to digital code does not end with mere acquisition but involves a process of elaboration, structuring, and information management, aimed at ensuring the usability, interoperability, and long-term preservation of such complex data.

The structuring of digital databases within the context of James I's Route

One of the aims within the project actions was to establish protocols for acquiring data that are replicable, with a focus in developing descriptive three-dimensional models and information systems for connecting architectural objects. In this regard, particular attention was given to the survey activities

[1] Moyano et al. (2022), *Operability of point cloud data in an architectural heritage information model*; Vital, Sylaiou (2022), *Digital survey: How it can change the way we perceive and understand heritage sites*.
[2] Parrinello (2019), *Preserving memory through image: landscapes and digital databases for documentation*, pp. 18-33.
[3] Parrinello (2023), *Documentare una rotta culturale tra procedure di rappresentazionee di materializzazione del paesaggio*, pp. 1806-1823.
[4] On the development of information platforms and data organisation for the structuring of information encoding systems, cf. *ex multis*: Parrinello, Porcheddu (2022), *Sistemi informativi dinamici a supporto della documentazione archeologica per interventi in emergenza*, pp. 48-65; Soler, Melero, Luzón (2017), *A complete 3D information system for cultural heritage documentation*, pp. 49-57.

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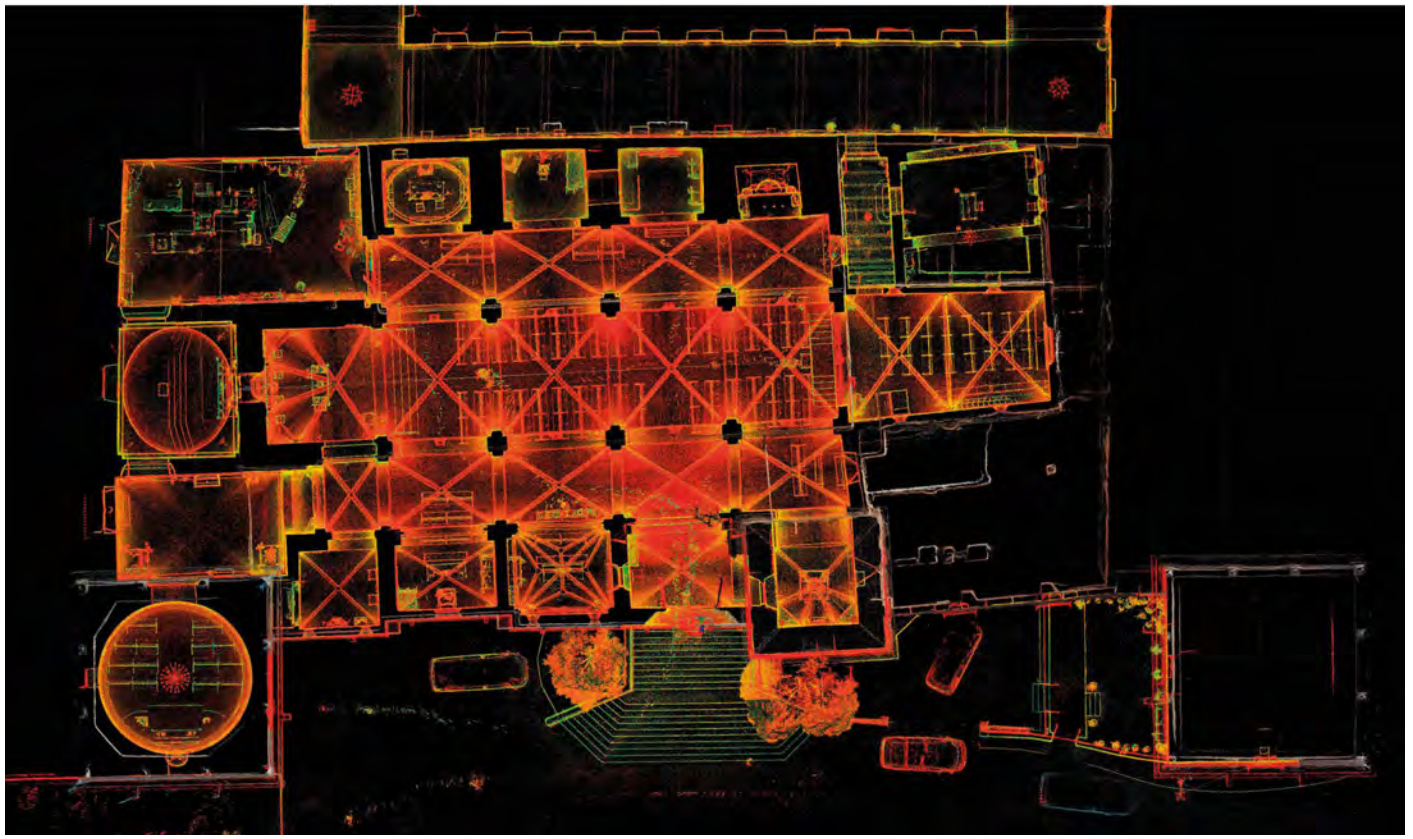


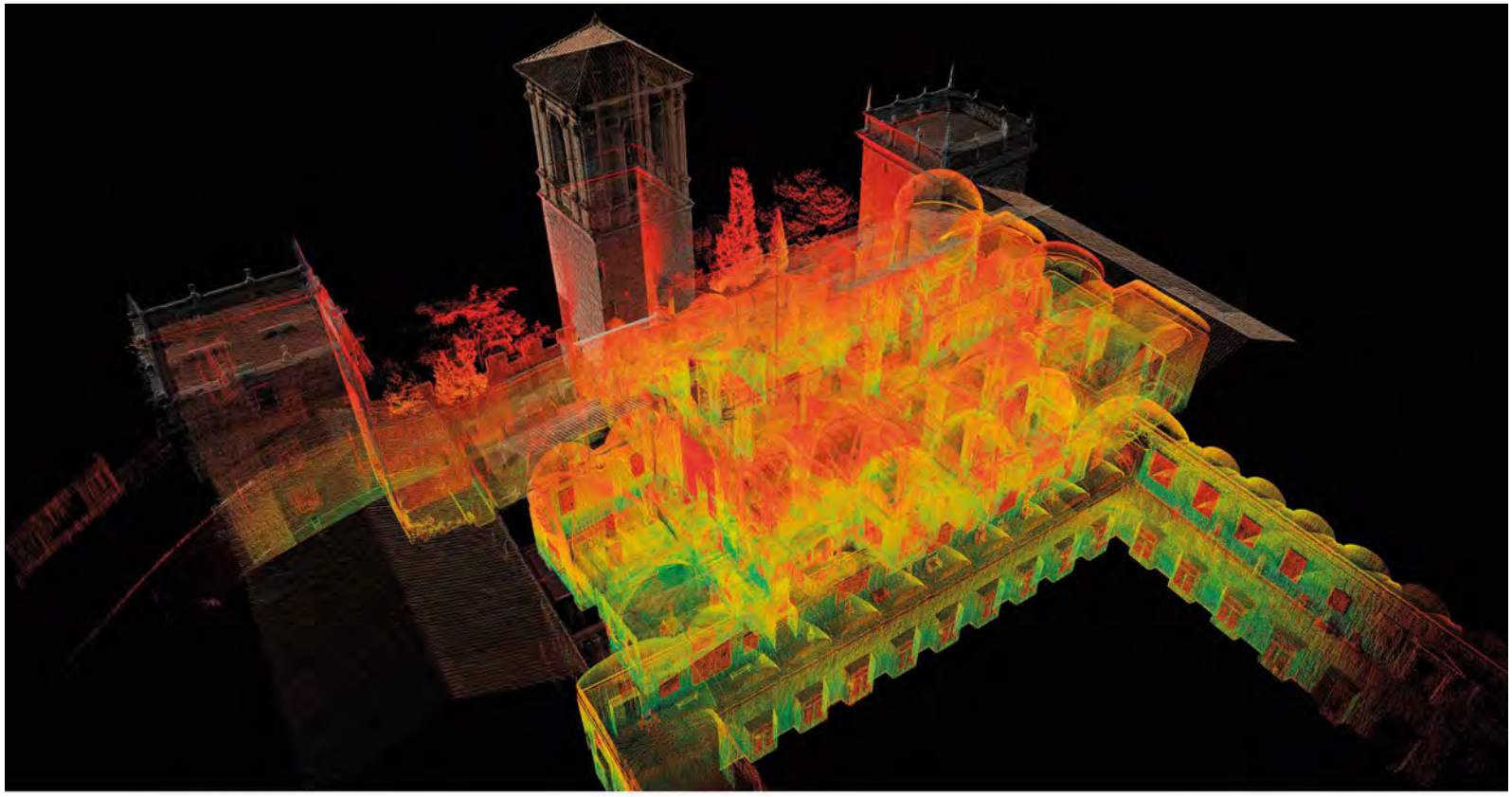
Fig. 02
Inside the building's limbs
Planimetric view of St.Mary Church inside the Monastery of Puig.

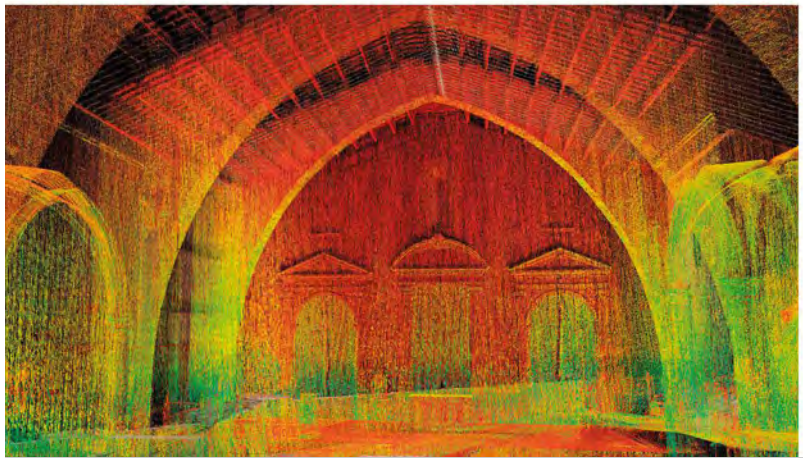
necessary for structuring multi-scale digital databases. The databases were used both as investigative tools for the morphometric understanding of the sites and as essential elements for creating digital outputs that describe the architectural heritage of the James I Cultural Route. In particular, the project actions involved experimenting with fast-survey methodologies through the combined application of *image-based* and *range-based* instrumentation, whose data, appropriately integrated, contributed to the production of multi-scale 3D databases, ranging from the architectural element to the building and up to the complex system of relationships at a territorial scale[5].

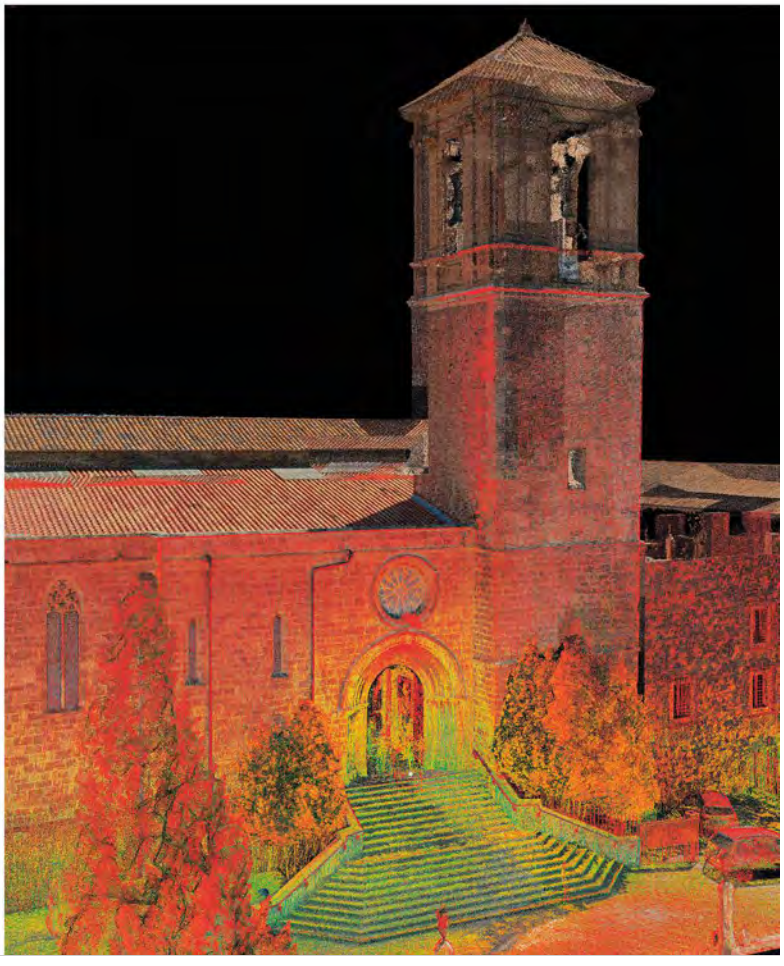
A significant area of experimentation that influenced the development of digital surveying methodologies, inside the project, was religious complexes[6]. In order to comprehensively document the heterogeneous characteristics and expressive richness of these architectures, the definition of surveying operations followed a protocol outlined in its general lines, but applied with different nuances for each case study analysed. The tangible differences in the characteristics of the analysed religious complexes, related to the varying focus on specific themes and the acquisition timelines defined during the planning phase, led to the establishment of surveying campaigns where photogrammetry techniques predominated, integrated, depending on the case study, with mobile and/or terrestrial laser scanner instruments.

Side page, Fig. 03
Religious Complex 3D database
Examples of multi-source databases from selected case studies along the Route.
Top and bottom right: Church of the Monastery of Puig.
Bottom left: Church de la Sangre (Llíria), exterior view and interior nave.

[5] Parrinello, Picchio (2023), *Digital strategies to enhance cultural heritage routes: from integrated survey to digital twins of different European architectural scenarios*.
[6] The development of databases related to the second area of interest of the route, the fortified heritage, has followed, in its general definition, the methodology proposed here for religious architectures.







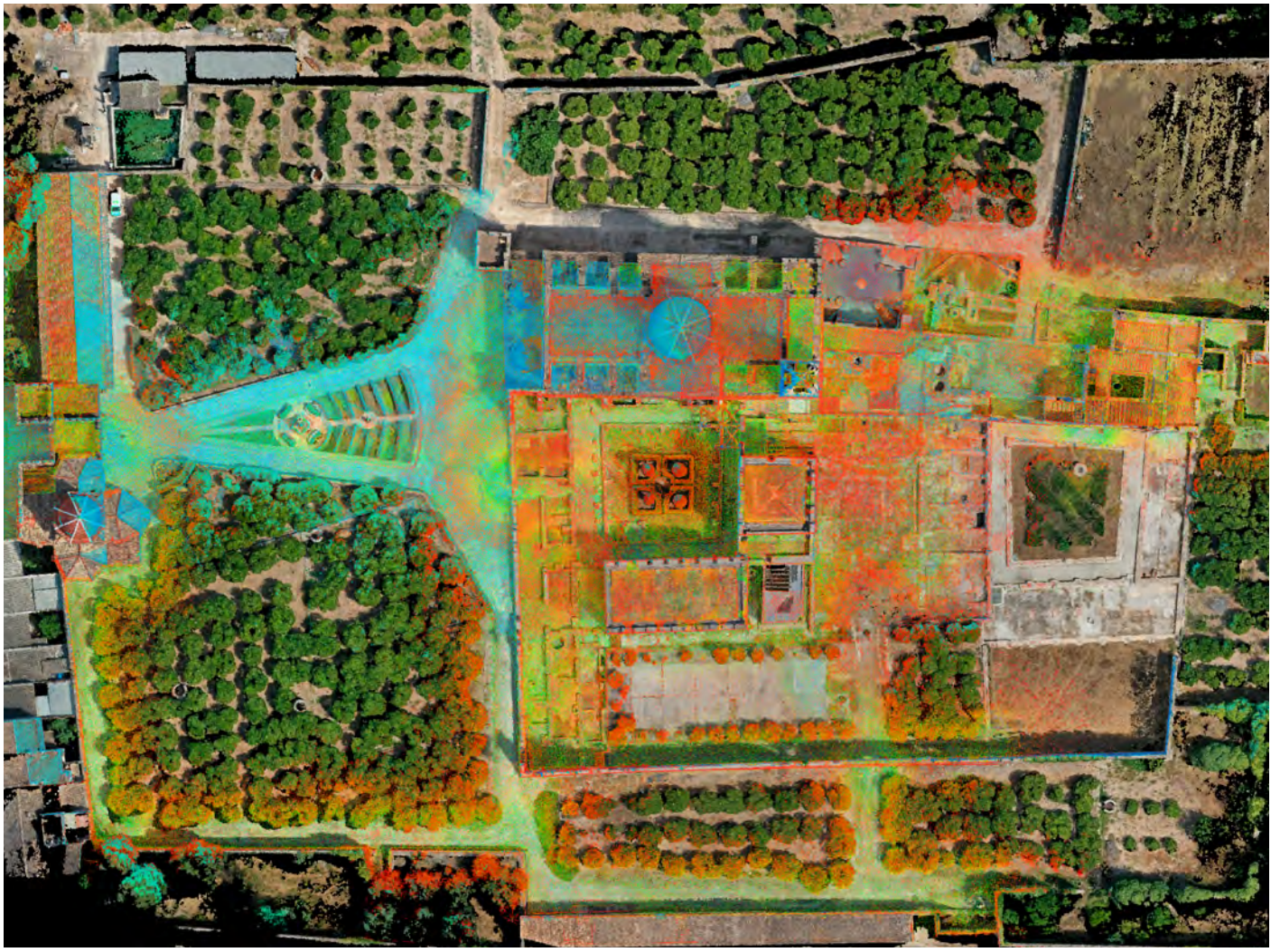


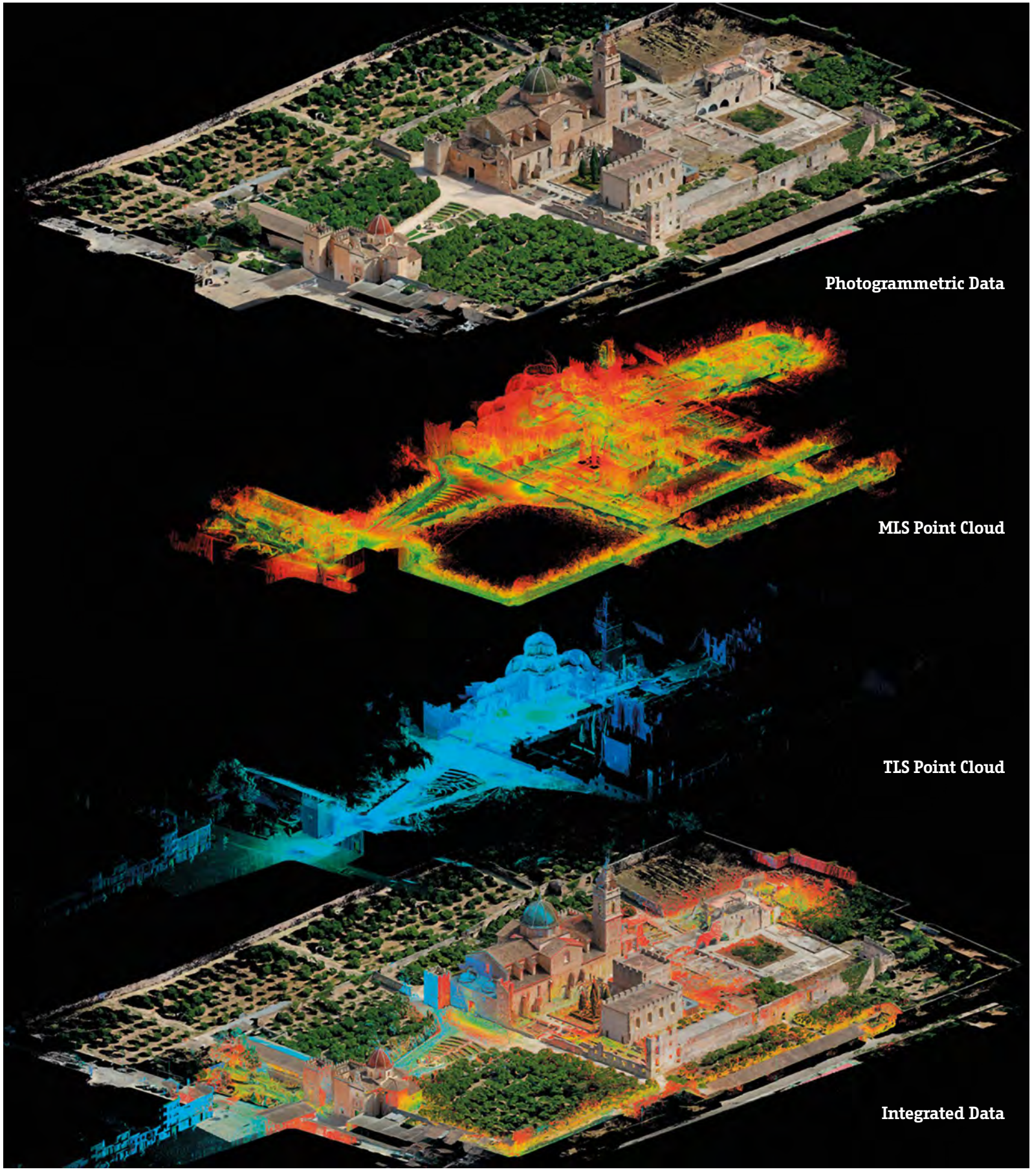
Fig. 04
Broad ensembles
Planimetric view of the point cloud of simat de la valldigna monastery.

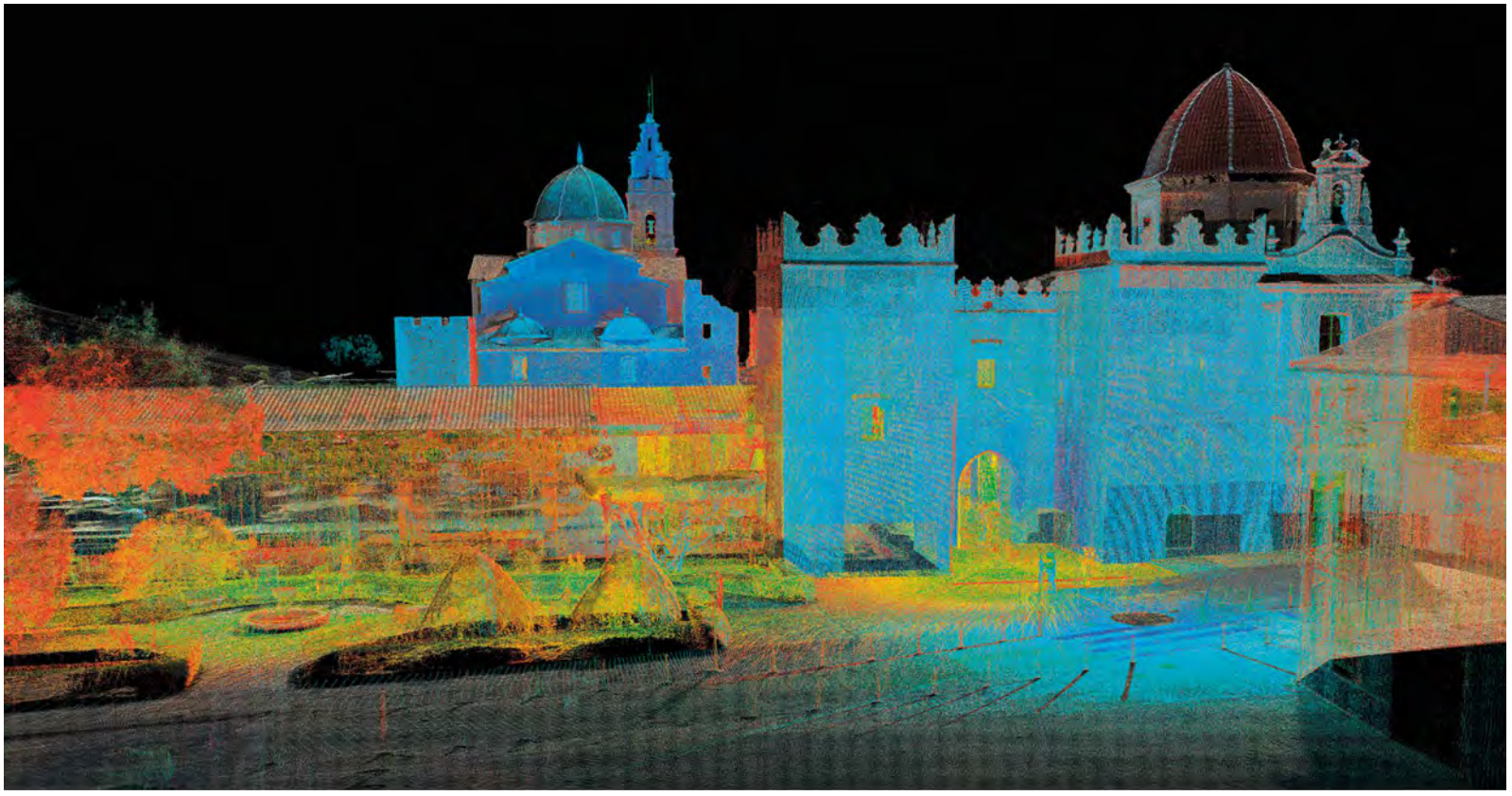
Side page, Fig. 05
Survey data integration
Axonometric diagram of the monastery's integrated database.

The varying levels of detail defined and the need to work within limited timeframes led to the creation of databases with different resolutions and detail levels. For case studies such as the Iglesia de la Sangre and the Church of Santa Maria del Puig, the photogrammetric acquisition was complemented by mobile laser surveying to ensure the morphological accuracy of the ensemble.

In other cases, such as the Cruz de Termino and the decorative elements of the Church of San James Apostol (Algemesi), photogrammetry was the predominant and, in some cases, exclusive tool for surveying operations. In these instances, the quality of the acquired images and the consolidated methodologies of photogrammetric survey[7], both on the ground and at height, resulted in databases

[7] The Structure-from-Motion photogrammetric surveying practices followed a methodological process already tested in various research projects. Similarly to the acquisition phase, the processing phase followed a consolidated workflow, from image alignment to the structuring of dense point clouds and mesh models, appropriately referenced and scaled based on direct measurement tools and laser scanning. For further insights on this topic, see Parrinello, Picchio (2019), *Integration and comparison of close-range SfM methodologies for the analysis and the development of the historical city center of Bethlehem*, pp. 589-595; Porcheddu, Picchio (2022), *Close-range photogrammetry for the production of models and 3D GIS platforms for archaeological rescue excavations*, pp. 112-121.


Photogrammetric Data
MLS Point Cloud
TLS Point Cloud
Integrated Data



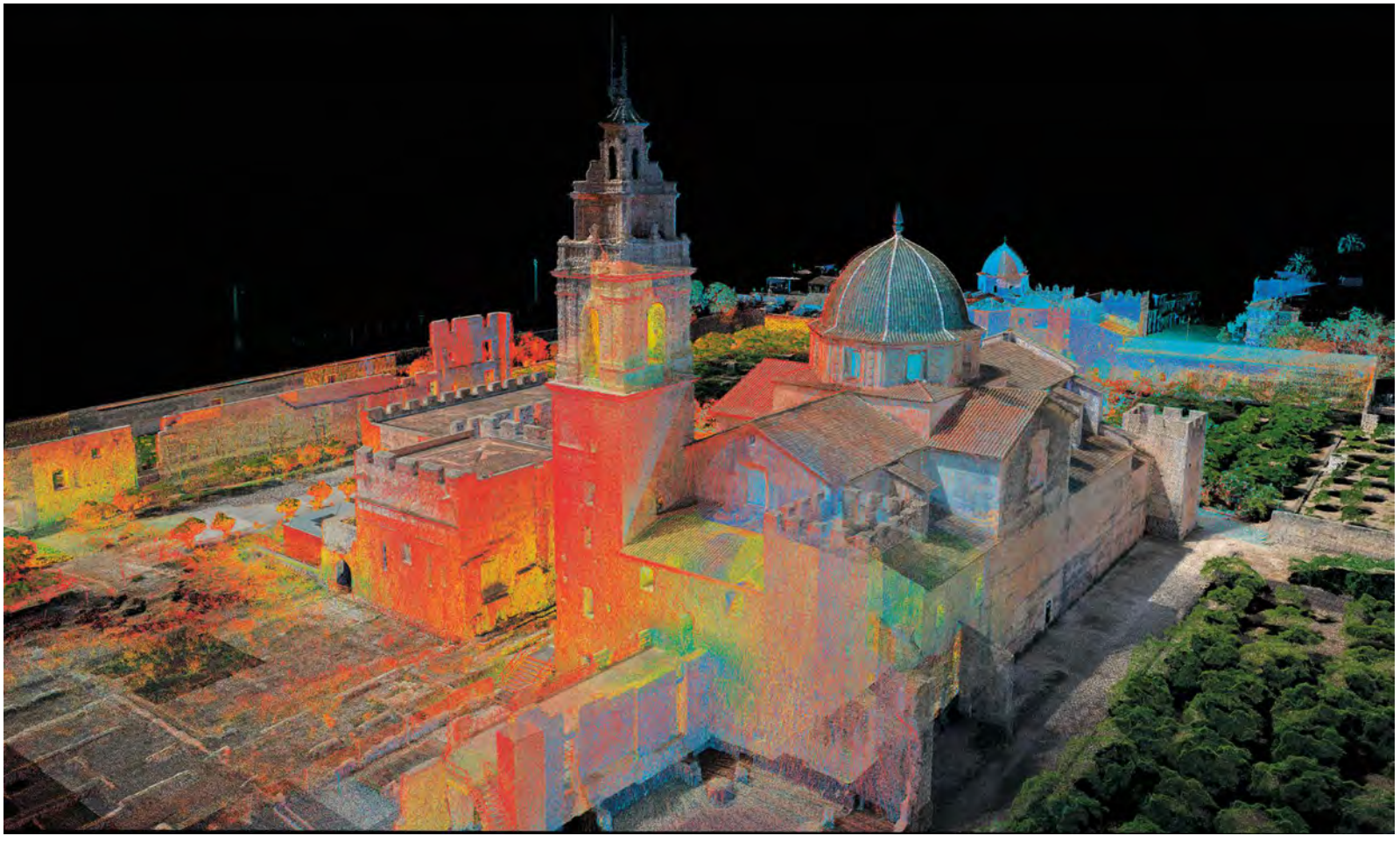


Fig.07
Church of St. Mary
Graphical editing of the integrated point cloud.

that were less competitive from a metric perspective but suitable for studying morphological features and conducting territorial-scale analysis[8].

In more complex contexts, such as the Monastery of Simat de la Valldigna case, the experimental approach used for defining the digital database involved the integrated use of three measurement instruments. Surveying activities were carried out by combining terrestrial laser scanning (TLS) and mobile laser scanning (MLS), alongside close-range photogrammetry techniques from the ground, using DSLR cameras, and aerial photogrammetry with UAV technologies.In this context, the terrestrial laser scanner was used to ensure the morphological accuracy of the digital database and to provide higher resolution data for specific areas. These areas include the interiors of the church, which feature a complex decorative apparatus, as well as the entrance building and the cloister.For secondary-interest areas and the open spaces around the main complexes, the acquisition was carried out using mobile LiDAR systems capable of quickly detecting and mapping.

In parallel with the structuring of the laser scanner survey, the use of UAV equipment for aerial photogrammetric acquisition was tested. The aim was to produce point clouds that were effectively integrated to describe each investigated monument comprehensively[9]. Ground-based photography

Side page, Fig. 06
Survey data integration
Perspective views of the integrated point cloud of Simat de la Valldigna Monastery.

Next pages, Figs. 08,09
Digital Database
Perspective views of the colorimetric point cloud of Simat de la Valldigna Monastery.

[8] The use of the photogrammetric tool alone was limited to case studies at a detailed scale or to architectural complexes of small dimensions, where metric accuracy was ensured by direct measurement of the main elements of the case studies.
[9] While using UAV equipment was useful for covering missing data on inaccessible surfaces, it also allowed for the description and representation of each analysed complex as a whole, thanks to the possibility of structuring georeferenced 3D models.

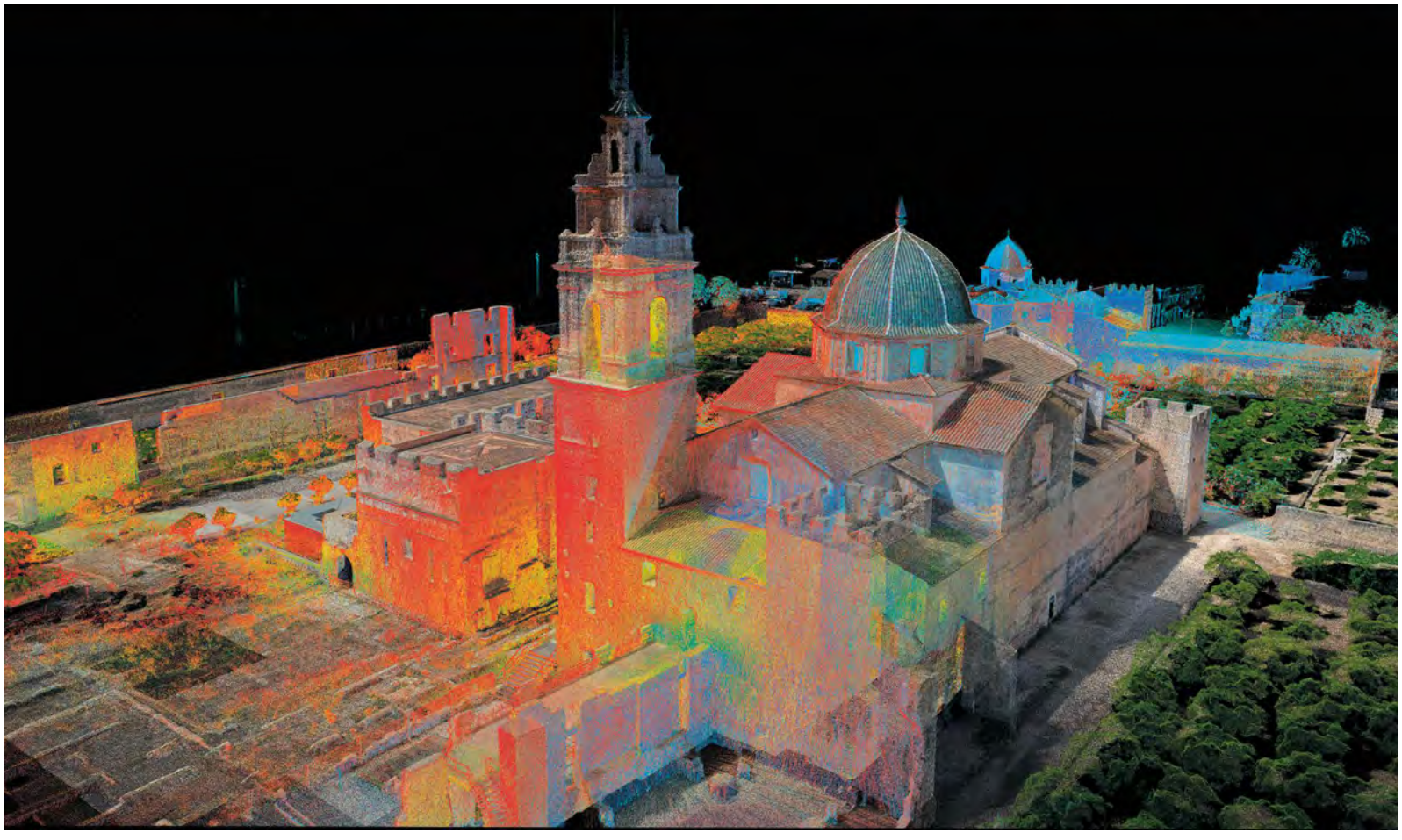


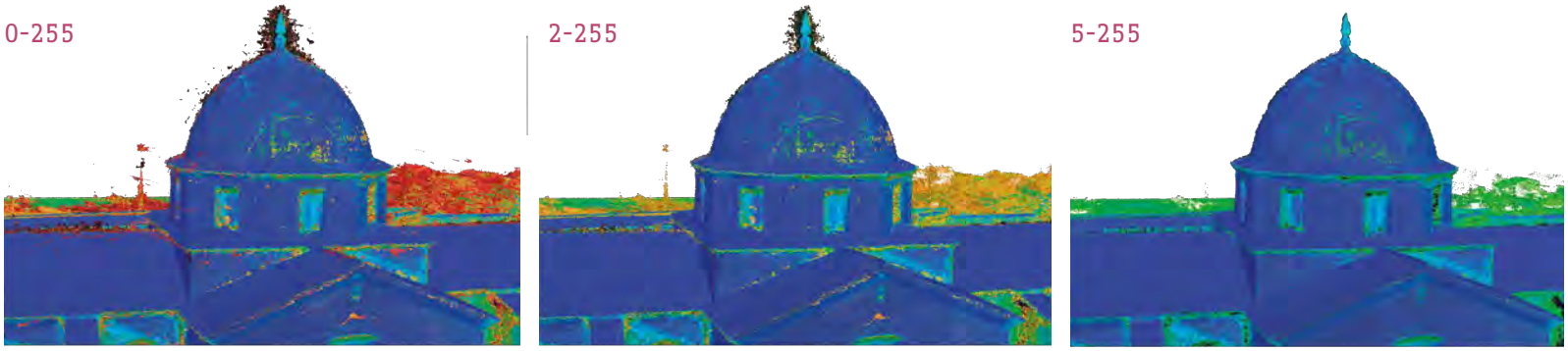
Fig. 10
UAV Survey data
Material and morphological quality of the photogrammetric data.

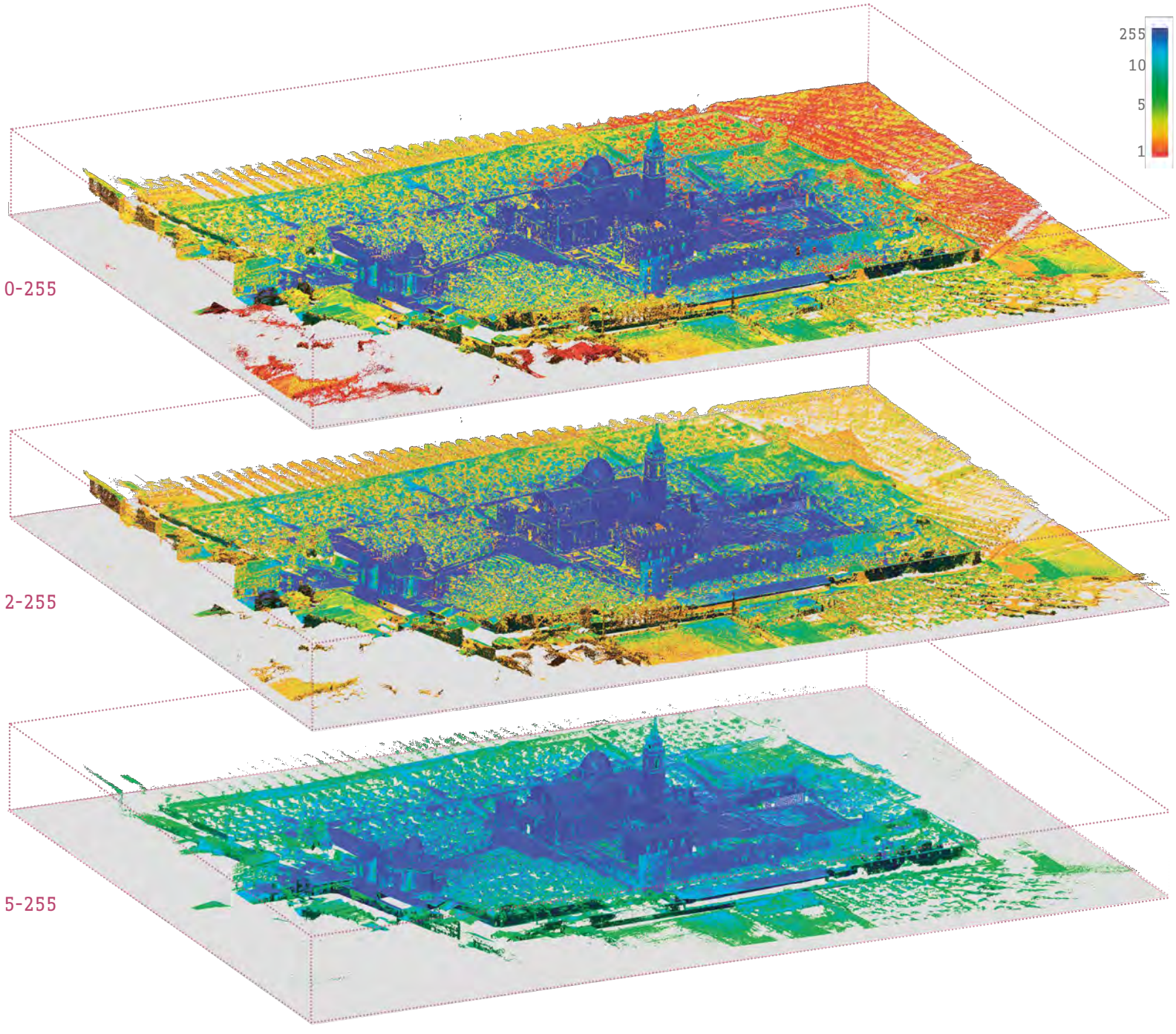
Side page, Fig. 11
Point cloud filtering
Schematic overview of photogrammetric point cloud filtering in Agisoft Metashape. Using the Point Confidence tool, the point cloud is filtered by setting a normalised value range between 0 and 255. Point Confidence expresses a relative reliability index related to the number of depth maps contributing to the reconstruction of each point, and is visualised using a colour scale.

was carried out to complete the documentation campaign, with particular attention given to surfaces that, due to their masonry texture or state of preservation, required higher resolution in the acquisition to be accurately described. The field data collection phase enabled the subsequent structuring of data organisation and synthesis processes by implementing digital databases for the analysed case studies. The implementation operations followed a methodological process in which the raw, heterogeneous data from the different instruments used were defined into individual instrumental datasets, which were then integrated and referenced to a common UCS.

When available, the laser scanner data, recorded through semi-automatic *cloud-to-cloud* processes, was used as the morphometric base for structuring the multisource databases. The result of these operations is a system of digital databases that provide the morphometric characteristics of these architectural complexes. These 3D databases serve as valuable tools for spatial analysis and understanding and a rich data source for subsequent implementations in digital modelling and structuring large-scale information system representation.

Photogrammetric Point Cloud - Point Confidence filter range





From 3D Databases to Systems for accessing Architectural Heritage

The methodology applied across different contexts enabled the acquisition of the multiple spatial and morphological configurations of the sites along the Route of James I, combining the morphometric reliability of the survey with the speed of field data acquisition. Digital surveying techniques allowed the collection of a large amount of geometric and informational data, providing an articulated and multiscale representation of architectural assets and their territorial context. Within this framework, three-dimensional databases assume the role of the primary structure for data integration, organisation, and analysis, enabling continuous comparison between real objects and their digital representations[10]. However, the informational richness of such databases may, in some cases, exceed the actual needs for documentation, interpretation, and enhancement of the sites along the cultural route. An excessive amount of data derived from digital surveys can lead to information overload, compromising readability and interpretative clarity if the data are not adequately selected, reworked, and discretised according to specific communicative goals[11]. Point clouds represent the foundation for an initial critical synthesis of spatial and metric information. They constitute the structural basis of the data, from which processes of selection, integration, and interpretation can be initiated. Photogrammetric data, when properly integrated and normalised with respect to metric data derived from laser scanning, provide a reliable basis for the construction of descriptive three-dimensional models. Although these models exhibit a lower level of geometric detail compared to reverse modelling directly derived from laser scanner point clouds, photogrammetry nonetheless allows for effective outputs in the enhancement of cultural routes, enabling immediate and integrated readings of different types of information.

At the same time, this representational synthesis may result in an excessive simplification of the forms and geometries of the digital duplicate compared to the real object, reducing the model's capacity to visually support certain categories of associated data. For this reason, the relationship between the real and the digital should not be understood as a simple transposition, but rather as a binary and dialectical relationship. The survey must provide a solid morphometric basis for the constructed model, while the model itself must be conceived as a structured tool capable of organising and conveying the collected information. Since the three-dimensional model represents the primary vehicle through which data are communicated, its structure must exhibit a level of complexity consistent with the nature and variety of the information to be managed. Appropriately segmented and semantically categorised models thus become interpretative supports for a wide range of historical, geographical, technological, and documentary content related to each case study along the route[12].

Side page, Fig. 12
From Building to Landscape
Conceptual outline of the information system and the possibility of relations.

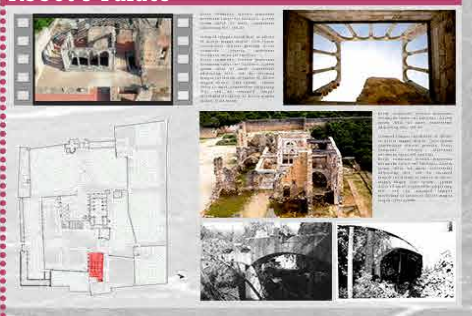
[10] De Marco, Parrinello (2021), *Management of Mesh Features in 3d Reality-Based Polygonal Models to Support Non-Invasive Structural Diagnosis and Emergency Analysis in the Context of Earthquake Heritage in Italy*, pp. 173-180.
[11] Picchio, Cortés Meseguer, Porcheddu (2023), *Disegnare un sistema informativo 3D per la promozione della rotta culturale di Jaime I a Valencia*.
[12] Franczuk, Boguszewska et al. (2022), *Direct use of point clouds in real-time interaction with the cultural heritage in pandemic*

Landscape

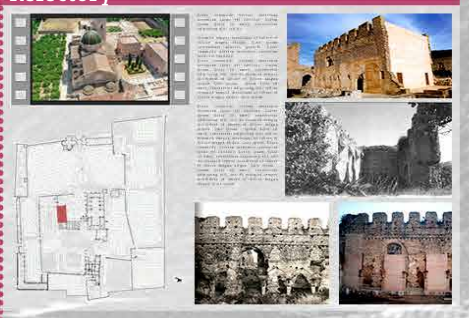
Monastery of Simat de la Valldigna

Building

Abbot's Palace

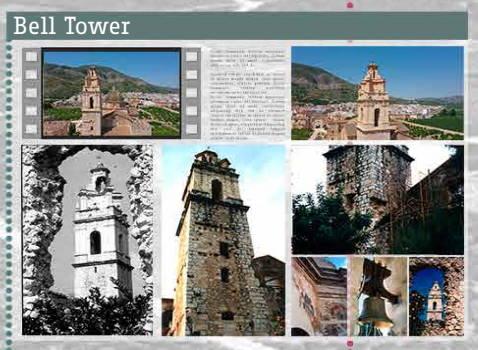


Refectory

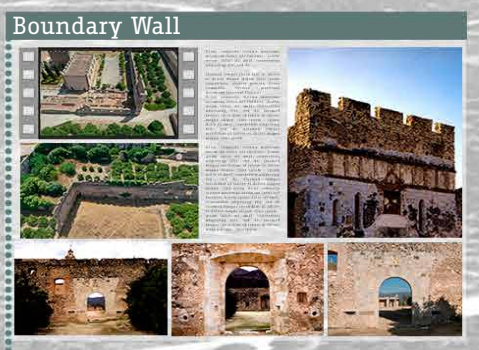


Element

Bell Tower



Boundary Wall



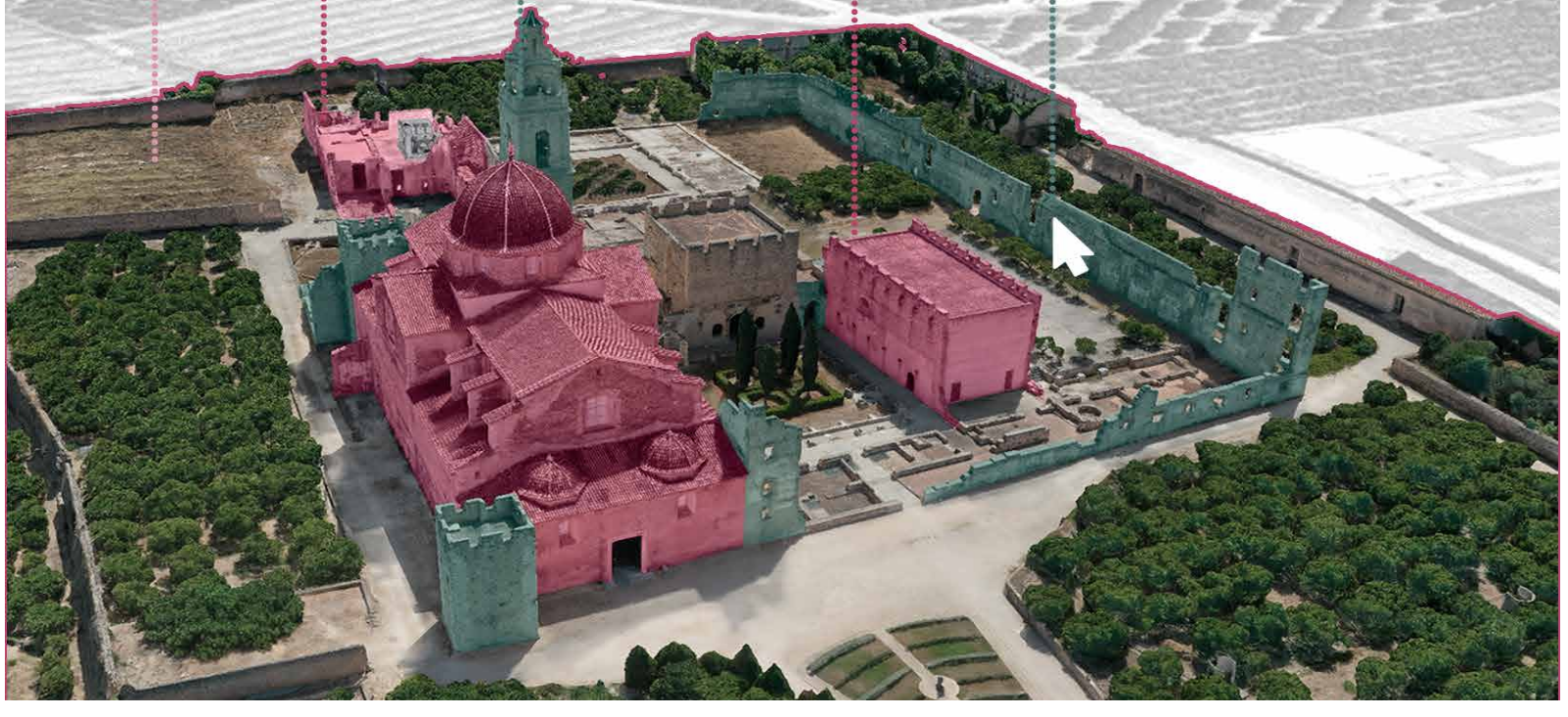


Fig. 13
From Real to its representation
From photogrammetric point cloud to textured model.

The organisation of elements within the cultural route, through effective strategies of segmentation and data management, whether based on point clouds or three-dimensional models, defines a structured framework for data archiving, consultation, and interpretation[13]. This process results from a conscious design action involving the integration and transformation of physical elements into their digital counterparts, where each digitised element may form part of a broader information system or constitute an autonomous, complete, and queryable database.

The need to make research results accessible to a wider audience through open-access platforms has guided the development of web-based information systems capable of associating optimised three-dimensional models—developed using BIM, NURBS, or Mesh modelling tools—with related multimedia and iconographic content[14]. The architectural elements composing the cultural routes, diverse in typology, territorial location, and historical evolution, are thus conceived as autonomous yet interconnected databases, capable of revealing relationships, meanings, and values that would not easily emerge through isolated interpretation.

and post-pandemic tourism on the case of Kłodzko Fortress; Picchio, Cortés Meseguer, Porcheddu, (2023), *Disegnare un sistema informativo 3D*, *cit.*

[13] Picchio et al. (2024), *Repositorio 3D para la puesta en valor de la Ruta Cultural de Jaime I en Valencia*, pp. 299-309.

[14] Cf. Beck, Borrmann, Kolbe (2020), *The need for a differentiation between heterogeneous information integration approaches in the field of "BIM-GIS Integration": a literature review.*

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