ICONARP
International Journal of Architecture and Planning
Received:19.12.2021 Accepted: 09.12.2022
Volume 10, Issue 2/ Published: 20.12.2022
Research Article
DOI: 10.15320/ICONARP.2022.207 E- ISSN:2147-380
ICONARP

Architectural Inventories. Evolution of Graphic Documentation of Heritage

Marta Quintilla-Castán*
Luis Agustín-Hernández**

Abstract

One of the main problems of the inventory of architectural heritage is managing and storing large amounts of information in different formats, in addition to the need to organize and manage the information generated by collaborative work between the different technicians who participate in the documentation process. The solution involves the development of a model capable of incorporating information on a layered support and allowing analysis and management, as well as interoperability between tools and other systems throughout the entire life cycle of the building. To carry out this work, two methodologies have been selected to verify their effectiveness in the field of architectural heritage inventory, covering the specific needs of generating a complete graphic database of the building. The Arches platform, a free open source software developed to carry out inventories, has been chosen for its interoperability, specificity and all the characteristics and functions described above. In turn, a WebGIS has been developed using free software standards and technology, to examine the possibilities it offers in relation to specific inventory programs. As a result, the creation of an Information System of the Mudejar Architectural Heritage of Aragón has been proposed, with the purpose of integrating under a common support, all the documentation and graphic information available on the heritage asset. The research limitations are the creation of a geo-referenced database, with geometric information on each building, which addresses the cataloguing of more than 200 assets, due to the uniqueness of this architectural style. The information is stored complying with the documentation standards to ensure interoperability and accessibility to the data.

Keywords:
Architectural heritage, graphic documentation, information system, inventories, mudejar

* Department of Architecture. School of Engineering and Architecture, University of Zaragoza. Zaragoza, Spain. (*Corresponding author)*
E-mail: mquintilla@unizar.es

** Department of Architecture. School of Engineering and Architecture, University of Zaragoza. Zaragoza, Spain.
E-mail: lagustin@unizar.es

To cite this article: Quintilla-Castán, M., & Agustín-Hernández, L. (2022). Architectural inventories. Evolution of graphic documentation of heritage. *ICONARP International Journal of Architecture and Planning,* 10 (2), 379-409. DOI: 10.15320/ICONARP.2022.207

INTRODUCTION

The preservation of the cultural values of the architectural heritage must be properly safeguarded, by registering the volumetric information and all the complementary information associated with the property. In this way, thanks to a correct graphic documentation, its investigation, conservation and dissemination is ensured (Gómez González, 2013). To carry out the work of documenting the architectural heritage, the storage of a large amount of information is required, which must be processed in various formats from experts from different areas of knowledge. This diversity of information hinders collaboration and proper communication between the professionals involved in documentation work, making interoperability and accessibility one of the biggest problems to be solved. Another disadvantage of traditional work methods is the limited transmission of information between different entities, not only between researchers or administrations, nor does it favor dissemination among the general public (Finat et al, 2010).

Traditionally, the information contained in architecture catalogues was made up of plans, photographs and texts, in two-dimensional format. But with the evolution of representation systems, their transformation has been linked to computer development. With current data acquisition techniques, exhaustive documentation of the heritage assets is generated, that allows obtaining a 3D geometric model, on which to dump data from the investigation. This situation implies new challenges, such as the storage and accessibility of information in an easy and intuitive way. The electronic dissemination of information is considered a solution that responds to most of the problems mentioned, since it allows permanent updating, flexibility, the ability to introduce any type of support, selective distribution, interaction with the user and lower costs of production (Gómez González, 2015).

This ability to generate information has favored the evolution of heritage records, by incorporating more complete and precise graphic documentation with respect to traditional architectural inventories. As a consequence, one of the main problems of the architectural heritage inventory is managing and storing large amounts of information in different formats and for multiple uses. It is an essential requirement to develop a methodology that organizes the process of data collection and information processing to ensure proper storage and accessibility to information. For this reason, the standardization and systematization of information from different sources is essential.

The objective is to generate an inventory management system that contributes to optimizing the management of stored information, as well as its updating, enabling interaction with other databases and thus, contributing to the dissemination of knowledge and the inventory of heritage. A common support that contains all the available materials of a heritage asset with the purpose of being stored, processed and analyzed, in order to facilitate its use for multiple purposes such as protection, restoration, conservation or dissemination, among others.

DOI: 10.15320/ICONARP.2022.207

The study area selected to carry out the graphic inventory of architectural heritage is the region of Aragon in Spain, since it concentrates a large list of assets, an example of the Mudejar heritage, exclusive to the Iberian Peninsula, whose time includes the twelfth century to the seventeenth century. Mudejar art is the result of the confluence of Muslim, Jewish and Christian artistic traditions in the peninsula, which has its own peculiarities in the Aragonese territory. This architectural singularity has favored its declaration as World Heritage by UNESCO. The complete registration of the Mudejar Architectural Heritage through the creation of a database represents a differentiating element with respect to the current state of the records available by the administration, by incorporating two-dimensional and three-dimensional graphic documentation that will provide more information regarding the registered buildings in a digital and accessible environment.

THE GRAPHIC DOCUMENTATION OF HERITAGE THROUGH INVENTORIES

Historical context of the evolution of heritage protection

The concept of heritage is a relatively recent term. The concept itself is constantly evolving and has been varying and expanding to the present day. The conceptual evolution of the term through the modification of the different regulations, have been altering and incorporating new meanings to understand how the treatment of these issues, derive in the need to carry out an exhaustive documentation of the heritage for its protection, conservation, management and diffusion.

The construction of the concept is flexible, and it is a recent process that began in the 18th century and continues to this day, as it is an open debate. The end of the 20th century has meant a renewal of conceptual and methodological approaches to the issue of Cultural Heritage (Azkárate et al, 2003).

In the 18th century, in the midst of the "century of enlightenment", reason and science prevailed in all fields of society. In the field of Heritage, documents, monuments and archaeology are beginning to be valued as sources of knowledge that must be preserved and transmitted, with the first debates regarding the selection of monuments to be preserved appearing. The search for historical truth, the rational criticism of the past, brought with it the development of archaeology and the appearance of the History of Art (Martínez Pino, 2012). As a consequence of the review of the past and the measures aimed at the conservation of the historical heritage, the first catalogues and inventories were proposed, as well as the first theories of restoration. Throughout the 19th century, after the French Revolution, the French Constituent Assembly made ecclesiastical, Crown and emigrant property available to the State, becoming part of the nation's heritage. This situation brought with it the need to deal with the management of innumerable assets, both movable and immovable, from an economic

ICONARP – Volume 10, Issue 2 / Published: 20.12.2022

point of view, “If antiquities are transformed into wealth, recent architectural works start to acquire, for their part, the historical and affective meanings typical of national antiquities. The concept of heritage thus induces a homogeneity of meaning in values" (Choay, 2007). The management model implemented entailed carrying out of inventories, the creation of surveillance and control mechanisms, through the Monuments Commissions, and the adaptation of the assets to new uses.

In the 19th century, the first theories of restoration emerged when considering the restoration of historical heritage as a scientific discipline. Highlight, the stylistic restoration led by Viollet-le-Duc, who advocated restoration, the archaeological restoration carried out by G. Valadier and R. Stern, or the theories of J. Ruskin, who advocated the conservation of monuments. Follower of these last theories, William Morris wrote in 1877 a manifesto questioning the stylistic restoration of Viollet-le-Duc. Later, Camilo Boito proposed the identification of the monument within a period and style, as well as the need to differentiate the transformations suffered during the consolidation process. Already in the twentieth century the architectural monument began to be valued in relation to its context. One of its exponents, G. Giovannoni heads the theory of scientific restoration, reflecting on the problems of the defense of historic centers, environmental respect and minor architectures. This theory is the basis of the international recommendations developed during the final decades of the 20th century.

It was in the last decades of the 20th century when the traditional concept of "historical-artistic monuments" was expanded, thanks to the texts generated by international legislation. There have been different texts that have given normative form to this conceptual and methodological evolution, such as the Athens Charter of 1931, the Venice Charter of 1964, the Amsterdam Charter of 1975, the Krakow Charter of 2000 or the Madrid Charter of 2011, among others. These Charters, have served to expand the concept of architectural heritage, replacing the concept of "monument" with others such as "cultural asset" or "heritage", as well as the expansion of the areas of protection of architectural heritage to the Complexes, to the Historical-Center, industrial architecture, vernacular architecture, etc. Specifically, the Athens Charter defines the artistic and archaeological heritage as a means to encourage the conservation of artistic and historical monuments, on the other hand, the Venice Charter, expands the previous views regarding the concepts of historical monument and monumental heritage, by including within these qualifications the most modest works.

The agents involved in the protection of Heritage, driven by the great changes, considered necessary the revision of the Venice Charter (1964), in which the international principles of conservation and restoration of monumental works were regulated to adapt them to the culture of each territory and the importance of "accurate documentation, consisting of analytical and critical reports illustrated with drawings and photographs," was specified. Since the 1972 UNESCO Convention

DOI: 10.15320/ICONARP.2022.207

(UNESCO 1972), whose purpose was to promote the needs of conservation and protection of Heritage, as well as "adopt the appropriate legal, scientific, technical, administrative and financial measures to identify, protect, conserve, revalue and rehabilitate that heritage", the different disciplines have collaborated to carry out this work jointly.

Historical context of the evolution of heritage protection

The advances that have been taking place since 2000, in the development of digital photogrammetry and laser scanning instrumentation, have constituted a revolution in data collection procedures, being able to obtain a large amount of very precise information, very quickly. In the same way, as this technology evolves, the information processing programs have been updated and numerous specialized programs have emerged in the treatment of very specific pieces of information.

This is precisely why, in the year 2000, the so-called Krakow Charter was born, in which for the first time a specific recommendation was made for the use of new technologies in the field of built heritage, defining in its fifth article "In the protection and public preservation of archaeological sites, the use of modern technologies, data banks, information systems and virtual presentations should be promoted". This fact, will officially mark the beginning of the use of new technologies as an effective tool in the conservation and dissemination of archaeological and architectural heritage. But it is in the ICOMOS Charter or Ename Chapter (2008), where the importance of the use of "virtual reconstructions" in the field of historical heritage is definitely exhibited, in the fourth section of Principle 2, "Visual reconstructions, whether by artists, architects or computer-designed, must be based on a detailed and systematic analysis of environmental, archaeological, architectural and historical data, including the study of written, oral and iconographic sources, as well as of the photograph". Its inclusion will constitute an important step in the search for the most suitable tool for virtual reconstruction, which brings together all the information ordered in the same database.

One of the main problems of the inventory of architectural heritage is managing and storing large amounts of information in different formats: alphanumeric information of technical and scientific data, raster and vector format of plans, maps, images, drawings, etc. In addition to the need to organize and manage the information generated by the collaborative work between the different technicians who participate in the heritage documentation process, which is why it is necessary to unify it in a common database. That is why for the complete documentation of the heritage and to be able to have exhaustive and useful inventories for all the contemplated uses, the Spatial Information Systems provide all the required functionalities.

An Architectural Heritage Information System requires a database that can incorporate information related to identification and location,

ICONARP – Volume 10, Issue 2 / Published: 20.12.2022

historical data, type of protection, geometric and constructive characteristics, state of conservation and types of intervention, and many more. The solution involves the development of a geometric model that allows including and relating information related to it. The format is a 3D model capable of incorporating information on a stratified support and allowing subsequent analysis and management, as well as interoperability between tools and other systems throughout the entire life cycle of the object.

There are numerous investigations, such as those studied below, that develop methodologies to document, intervene and restore architectural heritage using the potential of 3D models, but there is still no tool that integrates all the needs that architectural heritage requires, from the point of view of cataloguing. The integration of the volumetric model in the Information Systems is one of the determining aspects for the choice of the appropriate methodology for its implementation. It specifies that the information stored in the 3D model from the different technicians is not incomplete and is available for analysis. There are different technologies that allow information to be stored in the same model, such as HBIM (Historic Building Information Modelling), but the objective of this research is to focus on defining a georeferenced system for the inventory of Architectural Heritage. The solution to the problem requires adopting a methodology similar to Geographic Information Systems (GIS), which allow the storage of information in layers, the use of vector and raster data, as well as the use of analysis tools.

TOOLS FOR INTEROPERABILITY AND ACCESSIBILITY

Heritage documentation implies the management of large volumes of information, which must be stored under an organized and accessible structure for consultation. Various disciplines intervene in the sector, with highly specialized fields, which have to work simultaneously and together, so coordination and communication is essential to ensure the preservation and transmission of data in documentation processes. For this reason, the creation of a common data model favors interoperability and accessibility to stored information, thanks to the use of international standards related to the field of representation of architectural heritage, that facilitate the association of specific vocabularies and the use of formal ontologies. The use of open source software and language, guarantees the correct exchange of information and ensures its permanence and maintenance over time, despite continuous technological advances, helping institutions to maintain their wealth management systems. Another essential field to take into account is the use of semantic organization, integrating international standards for heritage inventory and documentation to carry out useful management of all data generated and implemented by all disciplines involved in heritage.

DOI: 10.15320/ICONARP.2022.207

Standardization

Cultural heritage requires the use of databases as an instrument to manage and inventory information. The collection, classification, analysis and presentation of information requires the use of protocols to order and use in a comprehensible and coherent way. To achieve compatibility between them, regardless of the information format, whether it is on paper or digital, multiple institutions are in charge of coordinating and adopting standards necessary for harmonization between them at different scales, in order to guarantee the survival and migration of data without long-term risks.

To allow interoperability between databases, there are a series of international standards related to the field of representation of cultural heritage and specifically architectural heritage, which allow the linking of specific vocabularies. The "Core Data Index to Historic Buildings and Monuments of the Architectural Heritage" Institute (1992) is a standard devised by the Council of Europe and the Getty Information in order to facilitate the documentation and standardization of architectural heritage and provide recommendations for technical standards for data capture and exchange. The standard was developed in parallel to another basic standard such as the "Core data standard for archaeological sites and monuments" (1995), a consequence of the collaboration between the CIDOC documentation committee of the International Council of Museums (ICOM) and the archaeological documentation group of the Council of Europe and whose mission is to complement the Core Data Index to Historical Buildings and Monuments of the Architectural Heritage in order to facilitate the integration of both in a single database.

In the field of heritage documentation, international inventory and documentation standards must be integrated, in order to carry out a useful management of all the data generated and implemented by all disciplines. To achieve these objectives, the ISO 15489 standard for Document Management was created. It is made up of two parts, the first contemplates a more generic scope, where the basic concepts, principles and requirements of document management are defined, in order to ensure the protection of information and that it can be retrieved effectively. The second part is a technical report focused on the methodological definition of the implementation of the contents exposed in the first part of the standard, where guidelines are established that shape the document management processes and instruments, as well as the need of use of metadata for the management of electronic documents and the requirements that must be met (Alonso, García-Alsina & Lloveras, 2007).

Finally, from the point of view of standardization in the field of geographic information, one of the main regulations to take into account is that established by the technical committee ISO TC211, whose purpose is standardization in the field of digital geographic information. In parallel, the OGC (Open Geospatial Consortium), based on the aforementioned ISO standards, has developed the GML (Geographic

ICONARP – Volume 10, Issue 2 / Published: 20.12.2022

Markup Language) standard, based on XML, focused on displaying geographic objects with the aim of allowing interoperability through the web. In addition, it is essential to name CityGML, an open data standard developed by the Special Interest Group 3D of the Geodata Infrastructure North-Rine Westphalia (GDI NRW) initiative, which is based on the ISO 191xx family of standards. It deals with the graphical and semantic representation at different scales of urban and landscape entities, based on time or structured at different levels of detail.

Ontologies

In the field of cultural heritage, to allow maximum interoperability and accessibility, the use of open source software and language, guarantees the correct exchange of information and ensures its permanence and maintenance over time despite continuous technological advances, favoring that institutions can maintain their heritage management systems, thanks to the use of formal ontologies (Doerr, 2009).

For the specific case of the dissemination of heritage through web platforms, it is necessary to take into account the use of Open Semantic Web Technologies in order to favor interoperability between 3D models and software, reducing the speed of visualization and effective use. of the resources. The person in charge of developing recommendations and standards for the exchange of information is being carried out by the W3C (World Wide Web Consortium) through the creation of standards such as XML, OWL, RDF or SPARQL. The use of these standards allows, in the field of architectural heritage documentation, to manage the amount of data stored in Information Systems, including 3D models.

The essential available tools for the development of the semantic web are ontologies and standard data models, which unequivocally specify the structure of the data and prescribe how it should be interpreted. There are several ontologies that deal with concepts or entities, which could be considered for some aspects of the study of architectural heritage. The main ontology used for the management of cultural heritage documentation is CIDOC-CRM "CIDOC Conceptual Reference Model", recognized since 2006 as an international standard ISO21127: 2014. CIDOC-CRM is compatible with other vocabularies such as those developed by the Getty Institute. The Art and Architecture Thesaurus (AAT) prepared by the Getty Institute is used to provide the semantic infrastructure, providing an ontology for the exchange of information on cultural heritage and the integration of heterogeneous sources. Specifically intended to cover contextual information, such as historical, geographical and theoretical backgrounds, it is composed of terms to be used in the description, access and exchange of information of objects related to art and architecture.

DOI: 10.15320/ICONARP.2022.207

GIS FOR THE ANALYSIS AND DISSEMINATION OF THE ARCHITECTURAL HERITAGE

Many different approaches have been taken to 3D visualization of heritage. For decades, it has been possible to verify how the use of Geographic Information Systems (GIS), are an adequate tool for the storage of information and its subsequent analysis, being able to effectively relate graphic information with any other type of data. This technology solves many of the visualization and annotation problems on geometric models, not only on terrain models or archaeological excavations, but also on objects and especially on buildings (Soler et al, 2017).

One of the main virtues of Geographic Information Systems is their ability to analyze large amounts of information in very different formats and for disparate uses. GIS technology allows multiple types of information analysis to be carried out, thanks to the use of overlay operations, network analysis, buffering and the like, as well as the use of thematic data to perform statistics, graphs, interpolations or thematic queries. The main characteristic that Geographic Information Systems provide is spatial analysis. When we talk about the documentation of architectural heritage, we are not only interested in the building, but also in its relationship with the urban environment in which it is located, as well as its relationship with the territory and the landscape. It is this capacity that differentiates it from other technologies that are also useful for the representation of heritage, such as BIM technology.

Traditionally, GIS have been designed to perform spatial analysis of the territory, allowing the inclusion of 2.5D geometric data such as DTM (digital terrain model) and DSM (digital surface model) models, in this way, surface analysis can be carried out, such as the calculation of slopes or elevations, and thus extract information about its shape to be related to other attributes. This same procedure can be used in the field of architectural heritage, especially in conservation and restoration tasks, since it allows 3D models to be integrated into the application from which information, such as deformations or profiles, can be extracted through the use of algorithms. Additionally, the organization of information is favored by the use of semantics through the use of ontologies that allow relating concepts and attributes in a given domain.

GIS technology is in constant development, its origin was thinking to work in 2D, but over time it has had to adapt and implement 2.5 D and 3D capabilities to be able to manage and analyze more complex data. These new requirements have meant great difficulties for GIS when it comes to managing 3D geometries and their topology, as well as for the analysis and geoprocessing of information. Currently, the OGC (Open Geospatial Consortium) continues to work to address the integration of 3D models resulting from different GIS, CAD and BIM technologies and favor the interoperability of the different formats for the creation of complete and fully accessible models. In the heritage field, the ability of GIS to add the time factor to spatial data is a useful feature to show the transformations suffered by a building over time and thus detect its deformations or other physical changes, obtaining a temporary 4D model.

In the field of architectural heritage documentation, different technicians intervene, such as architects, archaeologists, historians, engineers or curators, who must work on a common data model on which they must be able to consult and edit the information produced by each one of them in a database that stores different types of varied information in multiple formats. Therefore, an effective solution that facilitates interoperability and accessibility to archived information and its use by different actors for multiple and varied uses, is the publication of a GIS on the web. The so-called WebGIS allows access to information from any location, view, consult, analyze or export information in different formats. Structured data can be accessed that are accessible through an interface with different display styles that are adaptable depending on the use made of the information, and may be more technical or informative, opening the scope of possibilities of use.

GIS methodologies developed for the documentation of architectural heritage

The use of GIS requires the elaboration of precise models that allow to incorporate information and data in a detailed way to its surface, that entails work that must be carried out by an experienced person and in which considerable time must be invested to introduce the data (Scopigno et al, 2017). GIS technology originated to represent 2,5D models (terrain) or flat surfaces (building facades), but the latest developments in Information Systems, allow the incorporation of 3D models of point clouds, which help researchers to efficiently and accurately manage the documentation gathered during the study, analysis and intervention processes.

Methodologies focused on the use of GIS for conservation work are under development. In a first stage, it made use of two-dimensional images to represent views of the building (floors, elevations, sections), obtained with CAD tools, which were later used to create vector maps on which to link the information. An example of this typology is ARKIS (Salonia et al, 2003), an Information System focused on the restoration of historic buildings.

The incorporation of geometric information on buildings through the inclusion of 3D volumetric models in information systems opens up new possibilities in the field of graphic representation of heritage. Regarding the generation of the 3D model, different approaches can be distinguished, the first of which builds the model using parametric software (Autocad, 3DS Max, Rhinoceros), which is later integrated into the GIS. This form of modelling limits the accuracy of the documentation, as the level of detail in the model depends on the modelling process. Additionally, the use of GIS facilitates the incorporation of new requirements, such as the use of semantics to create an organized and accessible information structure over time. In this way, the database

DOI: 10.15320/ICONARP.2022.207

manages the information in an orderly manner and allows its relationship with other databases.

The MayaArch3D project develops a 3D WebGIS with the aim of creating an online archaeological repository, called QueryArch3D (Von Schwerin et al, 2013). In a spatial database, it incorporates 2D and 3D data in multiple resolutions and with different levels of detail, which allow to link archaeological data and make queries in real time in a virtual reality environment. The GIRAPIM software is made up of a Documentation System, an Information System and a Management System, which make up a modular architecture made up of three components: a viewer, a semantic repository and a CityGML manager (Calle et al, 2010).

The second of the approaches for creating a 3D model that is incorporated into an information system is through the implementation of a textured model, obtained by means of photogrammetry and laser scanner, from which a precise geometric model is obtained that represents the current state of the building. An example of this methodology is the SICAR Information System, promoted by the Ministero dei Beni e delle Attività Culturali e del Turismo (MiBACT) of Italy, as a tool to be used in restoration projects (Fabiani et al, 2016). Much of the information can be overlaid in vector shapes on the model using layers that allow data analysis. It is an open-source and on-line system dedicated to restoration, which allows georeferenced graphic, photographic and alphanumeric documentation, as well as it can be used to carry out queries, such as editing information. The University of Granada has developed the Information System called Agata (Soler et al, 2017), allowing specialists to interact with a 3D model and annotate vector and raster information directly on the model surface. In addition, it includes tools for spatial analysis, based on the topological, geometric or volumetric characteristics of the polygonal model. Agata is based on the Chisel system (Soler et al, 2012), which was discontinued because it did not support vector layers, semantic information, or large 3D models, being the wrong program structure.

The latest advances in GIS technology are related to the ability to incorporate information directly on the 3D model, that is used as a reference on which to link documentation or as a basis for obtaining two-dimensional data, as proposed in the framework of the Swedish Pompeei Project (Dell´Unto et al, 2016). The basic principle of this information source is to transfer a value from a traditional 2D layer (raster or vector) to the corresponding mesh element (triangle) that belongs to the horizontal copy of the facade superimposed on that 2D layer. In this way, all the information is layered in the GIS and linked to alphanumeric information (Campanaro et al, 2016).

The latest contributions in this field, focus on the development of information systems accessible in real time through web platforms and created with open source standards and technologies. These systems are capable of storing and managing information, prioritizing characteristics

ICONARP – Volume 10, Issue 2 / Published: 20.12.2022

such as accessibility and manageability by non-expert users. At the same time, the visualization and consultation of the 3D model is facilitated, thanks to its construction according to a semantic structure on which to record information stored in a database. Fulfilling these characteristics, Neptune Information System was devised, specifically developed to manage the documentation generated during the restoration process of the Bolonia Fountain of Neptune monument. (Apollonio et al, 2018). The system integrates a volumetric model divided according to a semantic structure, on which information is linked to each of the corresponding elements. The viewer is complemented by a panel where the information associated with the 3D model is represented and supports data analysis and operations. The solution generated to document the Neptune fountain has made it possible to develop a more complete information system called Sacher 3D Life cycle Management, specifically for management and restoration work (Apollonio et al, 2019). The system maintains the characteristics of the semantic model, and incorporates geographic, analysis and administration tools.

The examples described, must deal with the management of a large amount of information available in heterogeneous formats that must be organized in a suitable way to be accessible and useful. From the first examples, in which the representations were two-dimensional, to the inclusion of 3D models, an attempt has been made to optimize the visualization of the object and the data associated with it, thanks to the possibility of visualization through multiple views, the representation of time, the use of multiple formats or the management of relational and object-oriented structures.

Information Systems have evolved towards technologies developed with open source software, the use of standards, ontologies and the structuring of information and the 3D model itself under a semantic hierarchy. In this way, interoperability between databases is favored and long-term maintenance of applications is ensured, without large investments and ensuring accessibility for different types of users. The possibility of exchanging information through the web and its dissemination in different media and formats for disparate uses, is one of the great advances made to the representation of architectural heritage. However, there are still many issues to implement and improve.

It is necessary to point out the limitation of the functionalities of editing 3D models from the information system itself, which is why it is necessary to use external software for the development and management of complex projects such as those related to the conservation and restoration of heritage. These projects require detailed information on the components and structure of construction objects, which due to their complexity cannot be carried out exclusively through GIS systems. For this, many investigations use BIM technology. The integration of both favors the creation of a complete database capable of managing semantically enriched 3D models in a spatial environment (Saygi et al, 2013). For this reason, the use of data exchange standards such as IFC

DOI: 10.15320/ICONARP.2022.207

(Industrial Foundation Class) and CityGML (City Geography Markup Language) are of vital importance. Platforms that integrate HBIM/GIS have been developed, such as the so-called PINTA (Processing Information System for Architecture), a system that combines the functionalities of CAD and GIS systems, integrating different tools according to the AIM & SHAPE methodology. The reference model is a point cloud on which thematic layers of information are superimposed, working in a similar way to GIS. El modelo posee una estructura semántica jerárquica que se obtiene con algoritmos que permiten la auto-segmentación (San José-Alonso et al, 2009).

Siarch3D-Univaq (Centofanti et al, 2012) is another proposal whose purpose is to create a single 3D model created under a semantic structure capable of managing different documentation formats that, through the use of data and elements, allows relationships between them to be obtained. More recently CHIMERA (Bruno et al, 2020) is a web system oriented to the simultaneous input and visualization of data such as 3D meshes, point clouds, information, images, plans, etc. The information is organized in five hierarchical levels that allow managing objects according to the use that is going to be made of them. These allow the transition between different scales of representation without the need to create replicas of the objects at different levels of detail, the "object" being the central entity of the system.

As has been seen, all the applications developed have been specifically programmed for a specific project, since there is still no tool that includes all the needs that heritage documentation requires. The unique characteristics of historical heritage suggest that BIM / GIS integration can be the definitive tool for obtaining a complete management system.

Table 1. Comparative of the different methodologies developed for the documentation of architectural heritage

Reference	Platform	Mehtodology
Salonia et al, 2003	ARKIS	GIS information system, to organize all kinds of information, available as a web platform, WebGIS. Use the "Avenue" programming system to transfer specific functions of the GIS to the architecture. It has GIS functions, since it works with attribute tables associated with topological elements. Relate descriptive and graphic information, locating information in an exact geometric point.
Von Schwerin et al, 2013	QueryArch 3D	It integrates and visualizes 2D and 3D data in multiple resolutions and with different levels of detail, allowing 3D models to be linked to archaeological data and real-time queries in a virtual reality environment of attributes stored in a spatial database.
Calle et al, 2010	GIRAPIM	Creation of an integral hybrid system, composed of a Documentation System (Viewer), Information System (GIS) and Administration System. The Documentation System provides a common model to the systems, on which the information is provided, for which attributes are assigned to make queries. In order for the three systems to converge, it is necessary to define standards. The software of the three systems is made up of a Viewer (.collada), CityGML Manager, and a Semantic Repository. The 3D model is created with traditional programs (not point cloud), and has raster and vector documentation. To

		navigate through the content, there is a menu with a tree structure with a hierarchy of concepts to navigate through the content. It is not a web environment.
Fabiani et al, 2016	SICAR	Promoted by the Ministero dei Beni e delle Attività Culturali e del Turismo (MiBACT) of Italy, to be used in restoration projects. Much of the information can be overlaid in vector forms on the model using layers that allow data analysis.
Soler et al, 2012	CHISEL	Proposal for an information system based on octree. Design of a 3D information system that allows information to be associated with the surface of the object using technology that is similar to that used in GIS. The information is associated with its position in space, organizing the information in raster layers on the surface of the object, which is a triangular mesh. Focused on creating layers of information in models of small pieces of heritage. The Chisel system was discontinued because it did not support vector layers, semantic information and did not support large 3d models, being the wrong program structure.
Soler et al, 2017	AGATA	Agata is based on the Chisel system. It allows to interact with a 3d model and annotate vector and raster information. It is possible to query from the surface to the metadata and vice versa, since the data structure allows bidirectional relationships. It includes spatial analysis tools, based on the topological, geometric or volumetric characteristics of the polygonal model.
Dell´Unto et al, 2016	Swedish Pompeei Project	Objective to develop a set of digital methods to be used and adopted by conservation specialists using 3D GIS. Creating a three-dimensional system for data management, combining 3D visualization and analysis offered by GIS. The work methodology is the creation of 3D features generated from two-dimensional map attributes, that is, dividing the 3D model into flat facades and drawing on them the 2D thematic layers, and drawing a plan that is used as a system of reference. In this way, all the information is layered in the GIS and linked to alphanumeric information.
Apollonio et al, 2018	Neptune Information System	Information system capable of storing and managing information in real time, accessible through web platforms and created under standard technologies that allow interoperability between different databases, prioritizing features such as ease of use by non-expert users and model visualization. The program uses 3dhop technology to display the model. It works by creating a semantic 3D model, divided into elements according to a hierarchical structure, in which, through operations, information is associated with each of these elements that will be linked to the corresponding 3D model. The model is a high density point cloud with 1mm resolution.
Apollonio et al, 2019	Sacher 3D Life cicle Management	Proposal for the creation of an information system to manage the needs of cultural heritage. Based on the Neptune Information System. Specific for management and restoration work. The system maintains the characteristics of the semantic model, and incorporates geographic, analysis and administration tools. The 3D model has a semantic structure and information is associated with the model through thematic layers on the surface. In this case they have added geolocation and it is more focused on architecture. It is based on GIS, by having the information in thematic layers.

DOI: 10.15320/ICONARP.2022.207

San-José Alonso et al, 2009	PINTA	Development of a comprehensive 3DGIS solution, which integrates different tools for information processing, administration and visualization. The reference model is a point cloud on which thematic layers of information are superimposed, working in a similar way to GIS. This data can be raster or vector. To be an accessible and interoperable system, the model has a hierarchical semantic structure, which is obtained with algorithms that allow auto-segmentation and for which lexicons, thesauri and taxonomies must be specified. This semantic structure allows working with different levels of detail and interoperability with other databases.
Centofanti et al, 2012	Siarch3D-Univaq	Creation of an information system called Siarch3D-Univaq focused on being integrated with the Italian “Risk map” database. Use of ArcScene to visualize the 3D model created with traditional programs (it does not include a point cloud) since it maintains dimensions, georeferencing, topology and applied textures. Complementary information is already linked to the model. The 3D model cannot be made as a point cloud mesh, orthophotos of the different facades can be incorporated as textures on the model.
Bruno et al, 2020	CHIMERA	Web system oriented to the simultaneous input and visualization of data such as 3D meshes, point clouds, information, images, plans, etc. The information is organized in five hierarchical levels that allow managing objects according to the use that is going to be made of them. These allow the transition between different scales of representation without the need to create replicas of the objects at different levels of detail, the "object" being the central entity of the system.

Systems for the management and inventory of heritage

Technological advances in the field of Geographic Information Systems offer tools for the management of spatial databases, 2D and 3D visualization, analysis and web access. The union of all this technology focused on its use for inventory management, is a very powerful tool that is constantly growing and evolving.

Based on the need for standardization and standardization of information, we find several examples of Heritage Inventory and Management Systems, whose primary component is Geographic Information Systems. First, we describe SAHRIS (South African Heritage Resources Information System), created in 2011 by “The South African Heritage Resources Agency (SAHRA), whose main mission is to report crimes against heritage (Smuts, 2015). The Management System is an open source web platform, developed through Drupal, a content manager (CMS), which in combination with the Linux operating system, Apache web server, MySQL database and PHP language configure a system that integrates with GIS technology. SAHRIS has among its main functions: be a comprehensive system that serves as a repository of national heritage for the conservation and management of heritage, the management of permits to regulate the export and import of heritage objects, movements between museums, as well as the monitoring of heritage crimes.

The results of the study of various proposals focused on the development of heritage inventories, result in ad-hoc programs, that is, they do not use a specific and common software for the preparation of inventories. For this reason, Arches highlights an open source geographic information web platform developed by the Getty Conservation Institute (GCI) and the World Monuments Fund (WMF) for the purpose of creating and managing inventories of cultural heritage (Myers et al, 2016). Since its launch in 2013, organizations around the world are using the system to manage resources, such as the Barbados National Registry of Historic Places, Nepal Heritage Documentation Project (NHDP), Armed Forces Retirement Home (AFRH), Endangered Archaeology in the Middle East and North Africa or Global Digital Heritage (GDH) a private non-profit research and education organization dedicated to documenting, monitoring and preserving the global cultural and natural heritage.

Arches design has focused on solving the challenges faced by heritage institutions for the development and maintenance of inventories:

- Economy: Arches is open source software that has no cost.
- Customizable: Open source and a system structured in modules, allows it to be expandable, in different languages and configure any geographical location.
- Ease of use.
- Different levels of accessibility: You can create different user roles, allowing you to control access to the system.
- Standardized: For the maintenance and interoperability between databases it has been chosen to use international standards. The “International Core Data Standard for Archaeological and Architecture Heritage” (CDS) which is used as the basis for defining the fields in the generic version of the system, and the “Conceptual Reference Model” (CRM) used to provide the semantic infrastructure (Carlisle et al, 2014). In addition to the use of open source, it has been designed to access and process geospatial data based on standards from the "Open Geospatial Consortium" (OGC), making it compatible with GIS applications, as well as the main browsers and map services.

PROPOSAL FOR THE CREATION OF AN INFORMATION SYSTEM FOR THE INVENTORY OF MUDEJAR HERITAGE IN ARAGON

The region of Aragon (Spain) concentrates a large list of assets, representatives of the Mudejar architectural heritage, built during the period between the 12th and 17th centuries. Highlights the Mudejar architecture of Teruel, declared a World Heritage Site by UNESCO on December 28, 1986, to later extend the protection to all the Mudejar architecture of Aragon on December 14, 2001. It is a mixture of styles characteristic of the Iberian Peninsula, with its own particularities in the Aragonese territory, which reflects the survival of Muslim culture, while in the rest of the Christian West Gothic architecture predominates.

In Mudejar architecture, the typologies of fortress-churches are significant, as well as churches with a single nave with a polygonal apse with five or seven sides and simple ribbed vaults. Representative of this period are the structure of the towers, which resemble the minarets of

DOI: 10.15320/ICONARP.2022.207

Muslim mosques, composed of two towers, one inside the other, the stairs are located between them and the body is crowned with the bell tower, usually with a polygonal format. For construction it is common to use materials such as brick, stucco, wood, ceramics or plaster, the latter used especially for the realization of singular ornamentation, through the representation of geometric shapes and plant themes.

Due to the uniqueness of this architectural style, it is necessary to address the cataloguing of the more than 200 listed buildings that represent the Mudejar architectural heritage in Aragon and are part of the World Heritage, to ensure their correct documentation (Figure 1). For this, the creation of an Information System of the Architectural Heritage is required, that allows incorporating any type of graphic, documentary and informative information, relative to the identification and location, geometric, construction, protection, historical, conservation or intervention characteristics. A common support that allows housing all kinds of documentation on a geometric model of the patrimonial asset, for the elaboration of a graphical database that allows managing the diversity of contents and available functionalities, in a coordinated way, to the specialists involved in the protection, conservation, restoration and dissemination of heritage.

Figure 1. Examples of the Mudejar architectural heritage of Aragon (Spain)

To carry out this work, two methodologies have been selected to verify their effectiveness in the field of architectural heritage inventory, covering the specific needs of generating a complete graphic database of the building. The Arches platform, a free open source software developed to carry out inventories, has been chosen for its interoperability, specificity and all the characteristics and functions described above. In turn, a WebGIS has been developed using free software standards and technology, to examine the possibilities it offers in relation to specific inventory programs. The technical characteristics and functionalities of both tools will be analyzed, making a comparison between the two selected systems, in order to develop one of them in greater depth to carry out the digital graphic inventory of the Mudejar architectural heritage in Aragon.

Inventory using the Arches platform

Arches is a program developed by the Getty Institute, specifically for the preparation of inventories, study and manage heritage resources, both movable, immovable, people or events, as well as intangibles, related to historical and cultural heritage. Thanks to the characteristics of Arches, digital inventories can be created that describe geographic information, types, materials or conditions of heritage elements, which allow establishing relationships between resources.

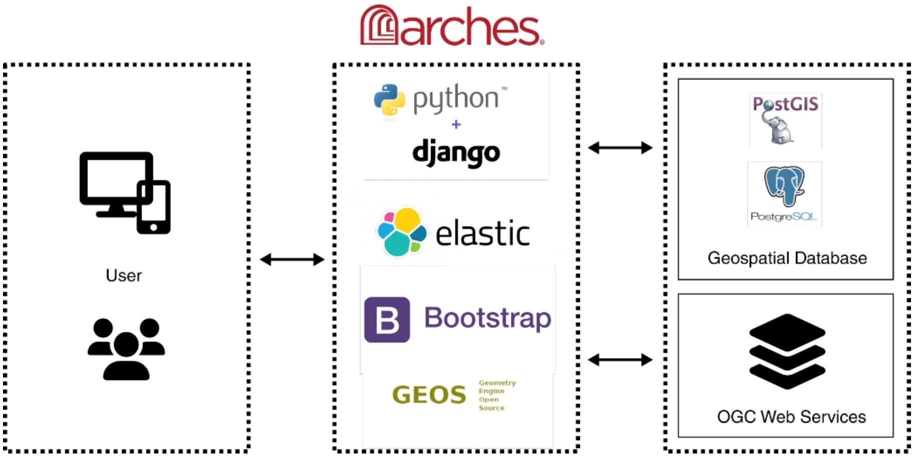


Figure 2. Conceptual structure of the Arches Heritage Inventory Package (HIP)

The Arches application is based on Python and Django and consists of a PostgreSQL relational database with PostGIS to store the spatial data. Arches uses the Elasticsearch search engine, which is built on top of the Apache Lucene library to perform scalable full-text search across large data sets quickly and easily. The information is accessible through a Bootstrap-based user interface, which uses Javascript. In addition, GEOS (Geometry Engine Open Source) is used to process geometries and perform spatial operations (Figure 2). Arches is distributed under an AGPLv3 license which allows users to copy and modify the application without restriction. The open source system allows for easy upgrades and modifications to requirements providing flexibility of extension and customization. On this basis, the incorporation or modification of the information associated with the record to be inventoried is simpler and more efficient, with more complete, exhaustive and accessible information. The registry is standardized and can contain as much written documentation related to the asset as necessary, created under the structure established by the main authorities in charge of inventory management, however, the incorporation of graphical documentation is limited.

DOI: 10.15320/ICONARP.2022.207

The system incorporates web and geospatial data processing standards, such as the OGC standard, which ensures compatibility with GIS applications and most web browsers. In addition, it is compatible with GeoJSON, KML and shapefile formats. Access to the inventory can be done through a web page with a standard environment and a search engine. As well as any type of base map can be used, such as the maps available from Google, Open Street Maps, Bing or other types of images provided by other geographic information services. Additionally, with the latest program updates, Arches Esri Link is now able to connect to ArcGIS Pro, making it easier for users to edit and add more information from within GIS software (Figure 3).

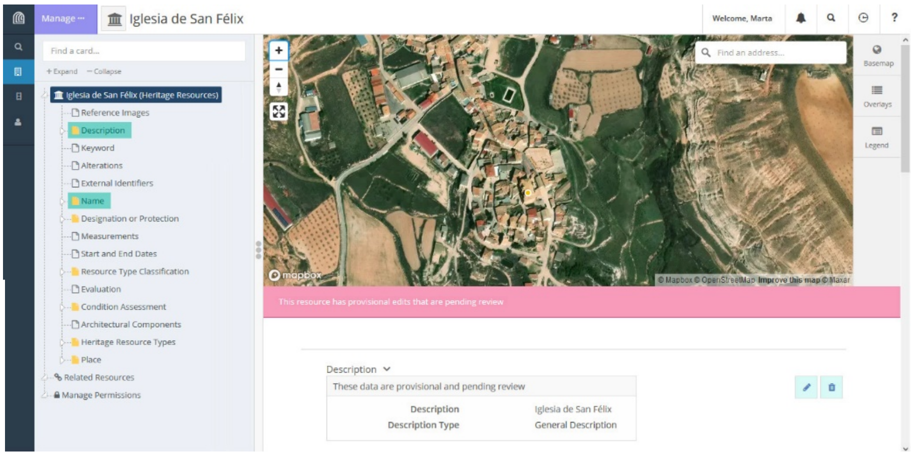


Figure 3. Inside the Arches Management System and the various features that can be populated from records. Example of the Church of San Félix in Torralba de Ribota (Zaragoza).

The database architecture makes it easy to implement any type of data model in a flexible way. For it, through the Arches Heritage Inventory Package (HIP) and with a differentiated data interface, different categories are established, such as: heritage resources, heritage resource groups, activities, historic events, actors and information objects.

The creation of the inventory database can be done in three ways, depending on the volume of data to be incorporated. Through the Resource Data Manager (RDM) form, you can enter the data manually in case the data is not numerous, since it is easy to use, but it is inefficient when you want to incorporate large volumes of data. To do this, it is possible to import the information from a file created with GIS, which allows geometry and attributes to be imported. Additionally, it is possible to import the information through a text file in "Arches" format.

Through the use of conceptual data models, Arches provides an overview of stored data and establishes a framework for organizing the data using a graphical data model (Figure 4). The model uses terminology defined by established controlled vocabularies, thesauri such as The Getty Art and Architecture Thesaurus (AAT), which favor unique identification and relationship building through the Reference Data Manager (RDM). Arches incorporates in its basic configuration, the international standards for the management of cultural heritage, CIDOC (International Commitee for documentation). To define the data types, properties, or relationships that describe a resource, the CDS standard

ICONARP – Volume 10, Issue 2 / Published: 20.12.2022

(Core Data Standard) to cover generic data and CRM standard (Conceptual Reference Model) to cover the semantic framework of data usage. The incorporation of this data with semantic content, allows to establish relationships and carry out advanced searches in the database itself, as well as between external databases, thus allowing interoperability between systems and the migration and conservation of data over time.

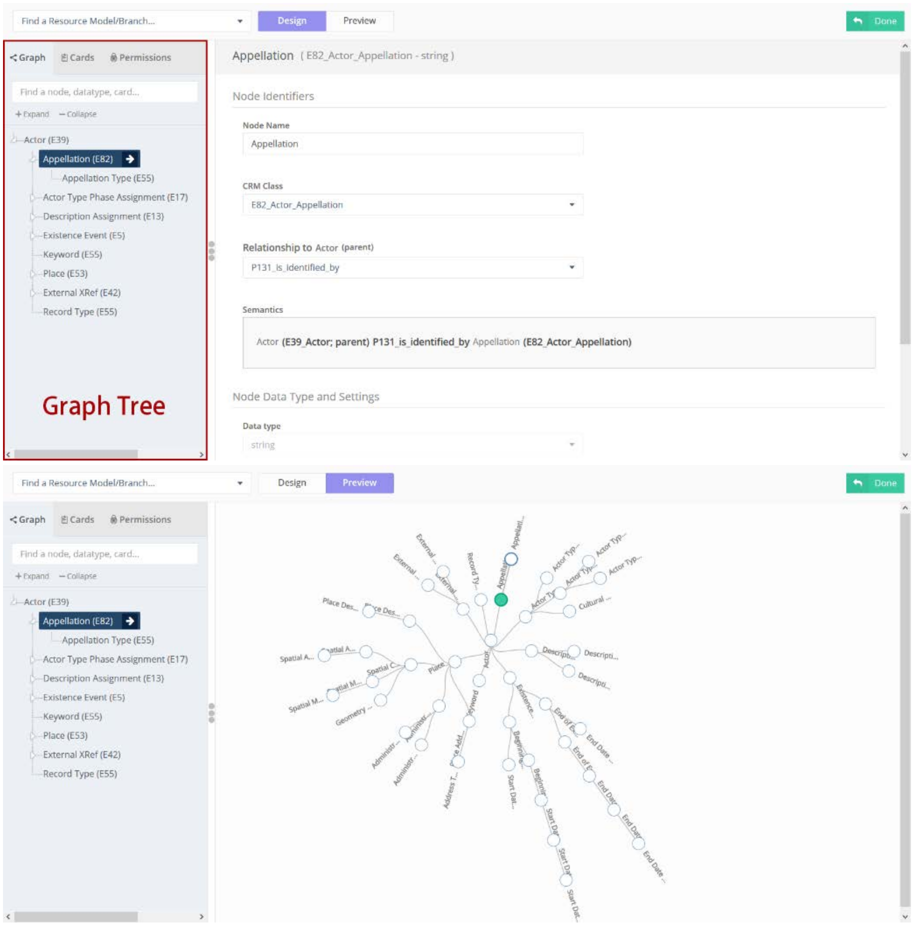


Figure 4. Arches provides an overview of stored data and establishes a framework for organizing the data using a graphical data model. Example from the Arches Modeling Documentation.

From the point of view of the visualization of two-dimensional and three-dimensional geometric documentation, the incorporation of graphic information is limited. Graphic documentation such as images or plans can be managed directly on the platform, but more complex documentation such as point clouds or meshes that represent volumetric information of the registered asset cannot be incorporated. For this, external platforms such as 3DHOP (Potenziani et al, 2015) or Potree (Schütz, 2016), both developed with open source software and based on WebGL systems capable of displaying high-resolution point clouds or meshes. Through an integrated viewer, allow access to graphic information of the textured three-dimensional model, where you can measure on the model itself or find additional information linked directly onto the 3D model.

DOI: 10.15320/ICONARP.2022.207

Inventory through WebGIS development

To carry out the inventory of the Mudejar Heritage in Aragon, a WebGIS has been developed in order to carry out administrative and protection tasks. The database allows the incorporation of information on the inventoried buildings, relative to the identification and location, historical data, type of protection, geometric and constructive characteristics, state of conservation and types of intervention. In addition, together with urban information and other types of information on the territory, they favor the generation of graphic information for spatial analysis and its use in conservation and dissemination tasks, since they contribute to provide a vision of the building on an urban and territorial scale, not only as an isolated entity (Figure 5).

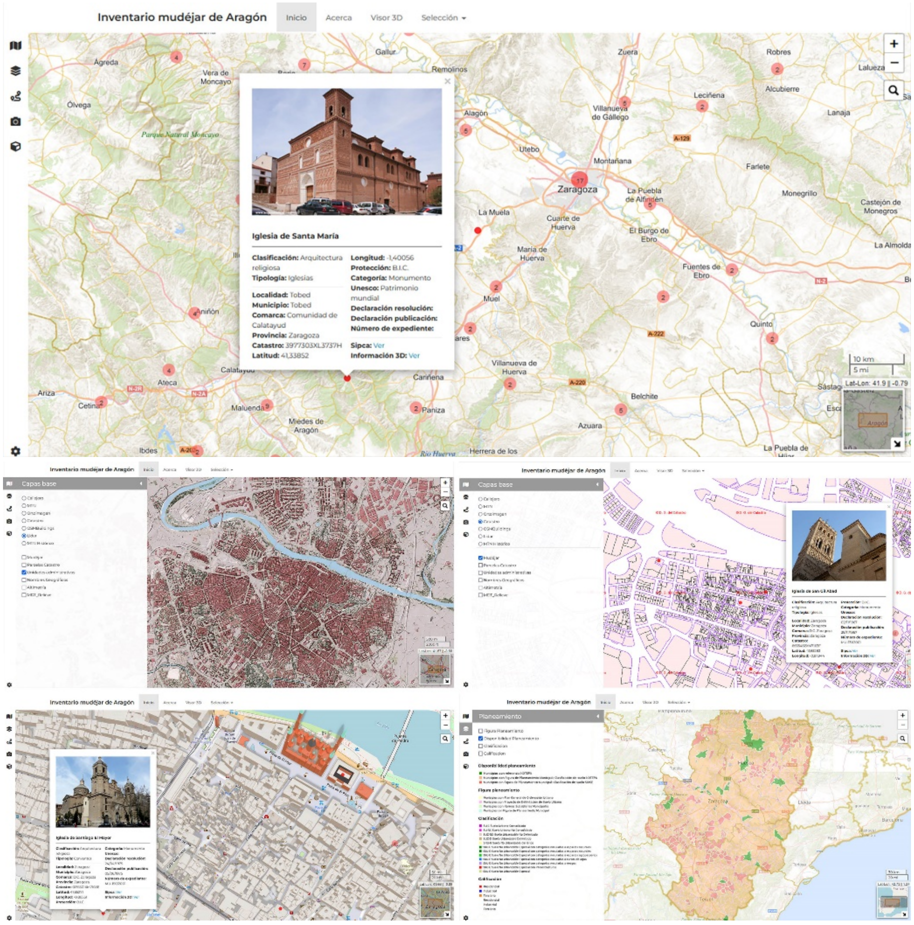


Figure 5. A WebGIS prepared for the dissemination of the Mudejar Architectural Heritage in Aragon. View of different thematic layers of information that provide urban information about the territory and the location and use of inventoried assets, as well as descriptive inventory information.

The accessibility to the information through a WebGIS, facilitates the access to structured data, consultation, analysis and export of the information in different formats, through an interface that allows to adapt the display style according to the use that the information is going to have, opening the scope of possibilities of use.

The System has been developed using tools that meet specific standards related to fields of cultural heritage, documentation, cartography or spatial data management, as well as the use of ontologies. The architecture of the system is made up of the QGIS software, a multi-platform Geographic Information System for the editing, visualization, analysis and management of spatial data, which allows managing raster and vector formats, as well as databases. PostgreSQL is used to manage object-oriented relational database systems through its PostGIS extension. It supports geographic objects allowing the creation of attribute tables with geometric and spatial information that are stored in a Geo-DB and performing analyzes through spatial SQL queries or through connection to Geographic Information Systems. Spatial Data Infrastructure services offered by different organizations that publish information through standardized web services and catalogue it using metadata have been used. The data is published through OGC standards, such as WMS, WMTS, WFS or WCS. Finally, the Leaflet JavaScript library is used to create web map applications, to be executed on the browser (Figure 6).

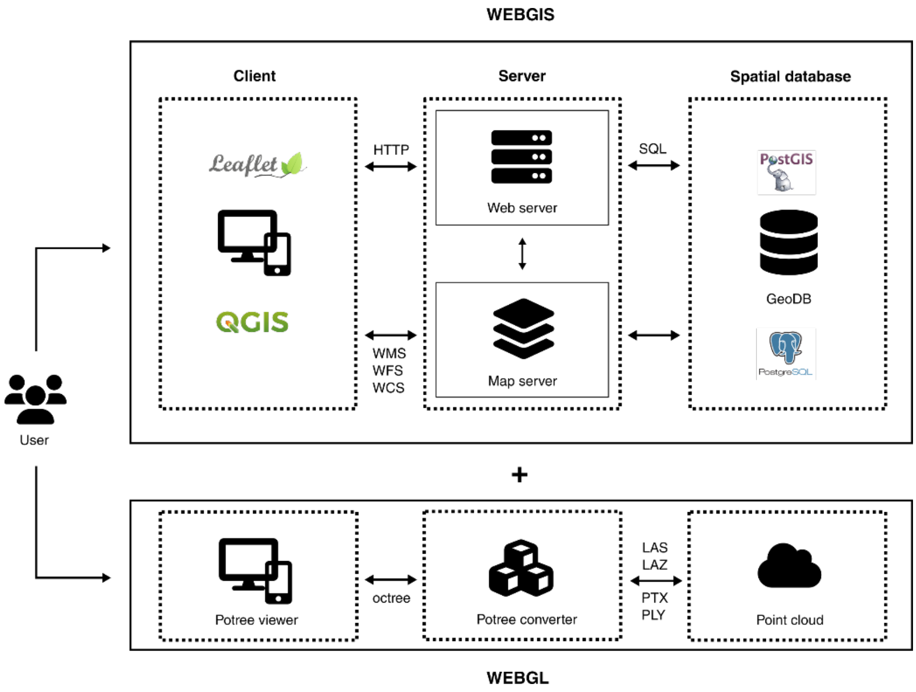


Figure 6. Conceptual structure of the web platform created for the Aragonese Mudejar Inventory.

The geometric documentation of heritage is represented by different levels of detail (LoD) in order to facilitate access to data, reduce latency and compression, by viewing and analyzing the same object at different scales and resolutions (Scopigno et al, 2017). The different scales range from the most generic vision, such as the LoD level 0, which represents the scale of the territory and the landscape, to the LoD 4, which describes the highest level of detail of the building, when representing constructive elements of the model. Intermediate levels of detail, such as LoD 1 reproduce the urban scale, without showing differentiated textures or structures, LoD 2 shows architectural models from an external view and LoD 3 defines the interior of architectural models (Figure 7). The first phase of WebGIS development has focused on reaching a LoD 0 and LoD 1 documentation level that provides an overview at the scale of the territory and landscape in the geographical area of Aragon and LoD 1 at the urban scale of the different locations where the inventoried assets are

DOI: 10.15320/ICONARP.2022.207

located. The graphic information consists of cartography, Digital Terrain Models, orthophotos, parcel and urban information, all of them coming from the IGN (National Geographic Institute), IDEARAGÓN (Spatial Data Infrastructure of Aragon) and the Cadastre. The different layers of information used in the viewer have been incorporated through a WMS (Web Map Service) and WMTS (Web Map Tile Service) request to the corresponding spatial data infrastructures. All the cartography has taken the ETRS89 Reference System, which corresponds to Spain and specifically for the study area, the UTM 30 projection axis is used.

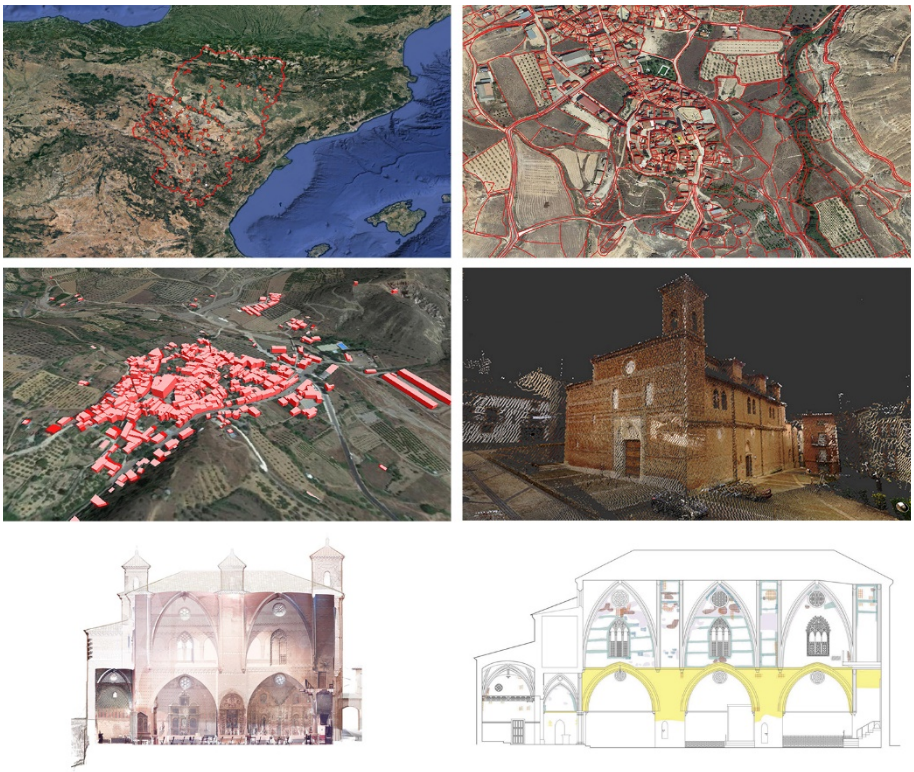


Figure 7. Different levels of detail (LoD) for the representation of heritage.

The information regarding the list of Mudejar architectural heritage assets in Aragon has been prepared manually after searching in various databases, since the Aragonese Cultural Heritage Information System does not have all the information and most of the records are not geographically located. The information regarding the inventory of the Mudejar heritage is stored in the Geo-DB by means of an attribute table that incorporates all the records organized in a hierarchical way and with a semantic structure according to the methodological framework of the project, using the "Core Data Index to Historic Buildings and Monuments for the Architectural Heritage" standard. The incorporation of urban and cadastral information, related to the list of inventoried and geolocated assets, allows more exhaustive analysis to be carried out and additional information to be obtained, by being able to relate the building to its surroundings (Figure 8).

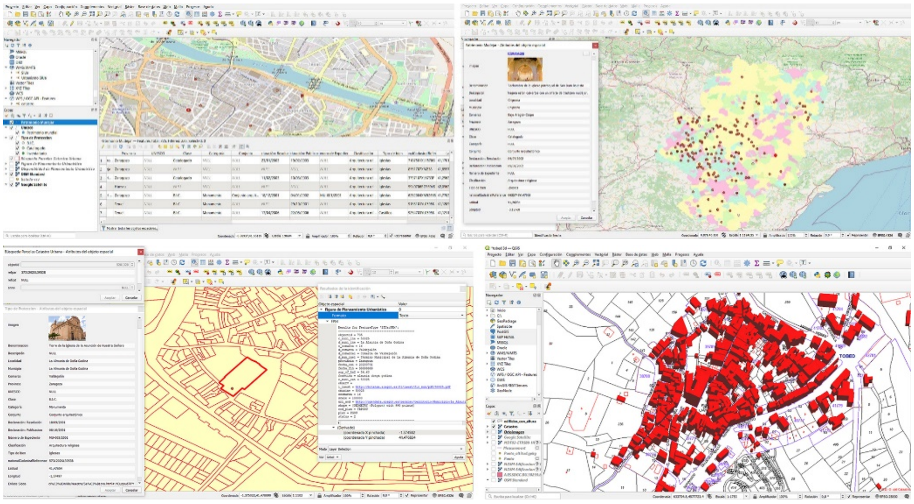
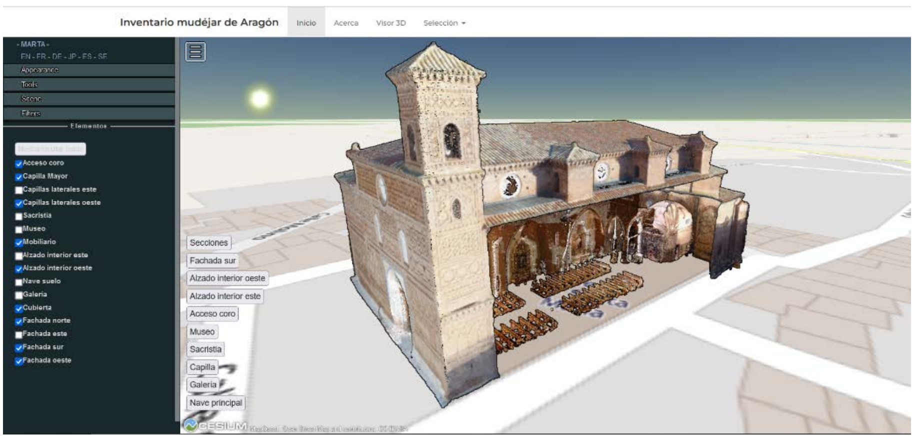


Figure 8. GIS showing thematic layers of cadastral information and urban regulations related to the inventoried building. (LoD 1 and LoD 2).

Through WebGIS, access is given to geometric information of the inventoried buildings using the open source Potree viewer, based on WebGL technology. It is a high-density point cloud viewer that allows you to manage two-dimensional and three-dimensional information on inventoried assets in a digital and accessible environment. The viewer displays 3D content through web browsers without the need to install additional software, providing great display speed. In addition, it has numerous functionalities to manage the point cloud and all the information associated with it (Figure 9). It is possible to modify aspects related to the appearance of the point cloud or the definition of the level of detail, as well as facilitating different types of navigation and access to data. It also has measurement capabilities and provides access through annotations on the model to other types of data with complementary information, such as text, plans, links, images, etc.

To complete the graphic information of the inventoried assets, in a second phase of work, the volumetric model of the inventoried buildings will be integrated into the information system itself, which will allow the thematic layers of information to be incorporated into the model itself (Dell´Unto et al, 2016), without the need to resort to external platforms. In this way, the value of the information will be enriched by contributing a greater volume of useful data to architectural inventories and with greater geometric precision.



DOI: 10.15320/ICONARP.2022.207

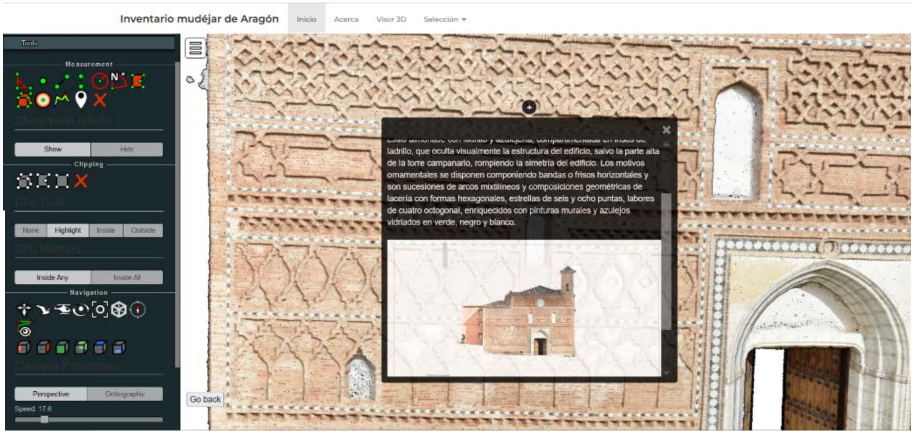


Figure 9. WebGL environment with the 3D point cloud of the Santa Maria church (Tobed, Spain) over the OpenStreet map layer (top). Example of complementary information associated to the general pointcloud view (bottom).

RESULTS

The main purpose of an inventory is the creation of an orderly database that allows the management of large volumes of information and is accessible. This accessibility, as stated above, is achieved through the use of standards for correct data storage, but also to facilitate the establishment of relationships between the different registered objects. To solve these needs, Arches is a powerful tool for the inventory and management of heritage resources, developed by expert professionals in the management of information and cultural heritage, which provides many advantages over other types of records. The main one is the ability to implement international standards such as CIDOC-CRM for the management of cultural heritage documentation, essential to promote interoperability between databases, as well as ensure their integrity. Like Arches, the WebGIS option also allows the use of international documentation standards for content management, however, the solution is better implemented in Arches since the graphic data model that structures the information is organized based on these standards. This content manager is easy to use and has numerous documentation and tutorials for the correct management of information, however, incorporating large volumes of information into the database is a challenge.

In this regard, GIS programs are capable of managing complex databases with varied information stored in very different formats, which provides the ability to analyze information from multiple points of view. In the case of architectural heritage, it implies the ability to establish relationships from a spatial and territorial perspective that has economic, social, environmental or cultural variables, among others, and must be understood as a network of relationships with the environment in which it is inserted.

Arches has many functionalities to manage the records, taking into account the maintenance of the data, the ability to evaluate the resources by updating criteria or managing them by reviewing the edition history. This ensures a properly organized and updated data structure that facilitates the maintenance of the application and the quality of the database. Due to its characteristics, the use of the tool by entities related

ICONARP – Volume 10, Issue 2 / Published: 20.12.2022

to cultural heritage involves little economic investment, but requires a developer with sufficient skills for its implementation. The software needs updates and sometimes there are problems due to new versions of the various components of the application. Like Arches, by developing WebGIS with open source software, the investment required to maintain the system is reduced and thus its maintenance is facilitated thanks to updates. This ensures accessibility to information and interoperability of data.

Both systems employ geospatial standards, such as those developed by OGC, with the aim of enabling interoperability through the web. The use of web standards also facilitates the creation of a multiplatform system that ensures easy access to information. In the case of Arches, it favors the development of a system capable of incorporating geographic information generated by other GIS applications, which facilitates the incorporation of additional layers of information for the study of heritage assets in relation to their surroundings. However, this capability is limited to overlaying information layers without the ability to perform spatial analysis, unlike what traditional desktop GIS programs can do by using overlay operations, network analysis, buffering, and the like. as well as the use of thematic data to carry out statistics, graphs, interpolations or thematic queries.

Finally, the ability to incorporate graphic documentation regarding inventoried goods is limited. Currently, and especially in the case of architectural heritage, thanks to the use of photogrammetry and laser scanning, 3D geometric models are available that provide extra information of great value on the objects inventoried. This information must also be correctly recorded and incorporated into the inventory. Arches needs the incorporation of external viewers to be able to visualize this type of information, so the model cannot be related to the spatial information of the GIS. The proposed WebGIS also allows the incorporation of 3D models through the use of external viewers, however, GIS have the ability, natively, to display 2.5D and 3D information. In the case of point cloud management, proposals are being developed for the creation of 3DGIS applications that are capable of displaying information efficiently and quickly, a problem that is constantly being updated and evolving through continuous updates of the software.

Choosing the right tool to create the architectural heritage record depends on the final use to be made of it. From the point of view of heritage inventory only, the Arches platform represents a great advance over traditional inventories by incorporating the geolocation of buildings and facilitating interoperability between databases. But for the specific case of architectural heritage, the component of spatial and territorial analysis is a value to be taken into account.

Once the differentiating characteristics of using Arches or the development of a WebGIS have been analyzed, it can be deduced that both options are good solutions for managing an inventory. However, in the specific case of the creation of a digital graphic inventory of the Mudejar

DOI: 10.15320/ICONARP.2022.207

architectural heritage in Aragon, it has been decided to completely develop the inventory through a WebGIS. In this case, it was desired to obtain an inventory with a large graphic component, both two-dimensional and three-dimensional, as well as to make use of the analysis tools provided by geographic information systems. In addition, it is desired to use the application as an element to promote Mudejar architecture, for which layers of information have been incorporated into the viewer for the realization of tourist routes as a means of valuing heritage.

Information on the inventoried building is generated from different points of view, spatial, geometric, metric or informative, which provides greater knowledge regarding traditional architectural inventories. The developed viewer is available at https://www.inventariomudejar.es/

CONCLUSIONS

The incorporation of Geographic Information Systems in the field of heritage inventory has meant an advance for the management by the organizations in charge of its elaboration, since it allows for complex analysis of the information, in addition to contemplating the geographic component. These characteristics facilitate its use for multiple purposes such as protection, restoration, conservation, planning and education. The creation of an Information System of the Mudejar Architectural Heritage of Aragon has been proposed, with the purpose of integrating under a common support, all the documentation and graphic information available on the heritage asset, with the purpose of preparing an inventory that serves various objectives, in this case, that enables spatial analysis for its conservation and dissemination. For this, two types of systems have been compared that allow obtaining a complete database of heritage.

Arches is an application developed specifically for the management of cultural heritage, designed with an extensive set of functionalities that allow the platform to be adapted for use by different areas and contexts. This versatility is obtained thanks to the use of the CIDOC CRM standard for the definition and storage of data. The use of open source software and standards facilitates their adoption and adaptation based on interests and needs, for the creation of data management tools in the area of architectural heritage. Its ease of use and the low cost due to the use of open source software, has motivated its use by organizations and entities that do not have IT departments or have limited funds, and in turn enables interoperability between heritage databases, favoring their management and integration in other databases, as well as their use for different utilities.

Arches represents a significant improvement over traditional architectural inventories, by introducing standards and facilitating interoperability between databases, but the incorporation of more complex graphical documentation remains to be resolved, with volumetric information on which to obtain complete information and the

ICONARP – Volume 10, Issue 2 / Published: 20.12.2022

ability to perform spatial analysis provided by Geographic Information Systems. In addition to the documentation related to the geometric model of the building, the GIS provide the additional value of spatial information, which together with the information related to urban planning, the territory and the landscape, they contribute to obtaining a global vision of the inventoried asset, since the buildings are not isolated entities, they are the consequence of their interaction with the urban and territorial environment.

At the moment, there is no system that includes all the characteristics of both technologies to create a graphical database that allows a complete inventory of the heritage and its use for multiple purposes. As has been seen, there are many proposals aimed at obtaining a system that allows managing information on a 3D geometric model, being a field that is constantly evolving.

The application of the technologies exposed throughout the investigation in the specific case of the Inventory of the Mudejar Architectural Heritage of Aragon has the objective of promoting its use by the administration as a means of activating new processes of knowledge, enhancement and use. Aragón has an enormous cultural and landscape heritage that is implanted in a territory that is not very accessible and dispersed, so it is essential to carry out actions to revitalize the territory from an economic and cultural perspective. The Information System provides an instrument that gives visibility to the architectural heritage as a means of analysis to identify the potential of the asset and the possible interventions to ensure its conservation, protection, promotion and management.

Currently, most of the registered assets lack precise graphic information, since due to the characteristics of the territory they are difficult to access for registration as they are located in rural environments. The creation of a digital repository made up of two-dimensional and three-dimensional information integrated into a geographic information system helps to consider heritage from a territorial perspective and provides the context to recognize its identity and cultural values.

ACKNOWLEDGEMENTS

The Architecture Research Group of the University of Zaragoza GIA, to which the authors of this work belong, is financed by the Government of Aragon (Reference Group T37_17R) and is part of the Institute of Heritage and Humanities (IPH) of the University of Zaragoza.

REFERENCES

Alonso, J. A., García-Alsina, M., LLoveras, M. R. (2007). La norma ISO 15489: un marco sistemático de buenas prácticas de gestión documental en las organizaciones. *Revista de Biblioteconomia i Documentació*, 47, 41-70.

Apollonio, F. I., Basilissi, V., Callieri, M., Dellepiane, M., Gaiani, M., Ponchio, F., ... Sobra´, G. (2018). A 3D-centered information system for the documentation of a complex restoration intervention. *Journal of Cultural Heritage*, 29, 89–99.

DOI: 10.15320/ICONARP.2022.207

Apollonio, F. I., Gaiani, M., Bertacchi, S. (2019). Managing cultural heritage with integrated services platform. *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLII-2/W11, 91–98.

Azkarate, A., Ruiz de Ael, M. J., Santana, A. (2003). *El Patrimonio Arquitectónico. Plan vasco de cultura*. Vitoria, Servicio Central de Publicaciones del Gobierno Vasco.

Bruno, N., Rechichi, F., Achille, C., Zerbi, A., Roncella, R. & Fassi, F. (2020). Integration of historical GIS data in a HBIM system. *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLIII-B4-2020, 427–434.

Calle, J., Martínez, R., Delgado, F., Finat, J., Hurtado, A. (2010). Towards an integration of documentation, information and management systems in a common framework. *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XXXVIII-4.

Campanaro, D. M., Landeschi, G., Dell'Unto, N., Leander Touati, A.M. (2016). 3D GIS for cultural heritage restoration: A 'white box' workflow. *Journal of Cultural Heritage*, 18, 321–332.

Carlisle, P. K., Avramides, I., Dalgity, A., Myers, D. (2014). The Arches Heritage Inventory and Management System: a standards-based approach to the management of cultural heritage information. In *CIDOC Conference: Access and Understanding - Networking in the digital era*. Dresden, Germany.

Centofanti, M., Continenza, R., Brusaporci, S., Trizio, I. (2012). The architectural information system SIARCH3D-UNIVAQ for analysis and preservation of architectural heritage. *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XXXVIII–5, 9–14.

Cerutti, E., Noardo, F., Spanò, A. (2015). Architectural heritage semantic data managing and sharing in GIS. In *GISTAM 2015 - 1st International Conference on Geographical Information Systems Theory, Applications and Management, Proceedings*, pp. 121-128. Barcelona, SciTePress.

Choay, F. (2007). *Alegría del patrimonio*. Barcelona, Gustavo Gili, 85-88.

CIDOC Conceptual Reference Model (2022). CIDOC CRM Special Interest Group. https://cidoc-crm.org/

Core Data Standard for Archaeological Sites and Monuments (1992). Documenting the Cultural Heritage. Los Angeles: J. Paul Getty Trust.

Core Data Index to Historic Buildings and Monuments of the Architectural Heritage (1995). Documenting the Cultural Heritage. Los Angeles, J. Paul Getty Trust.

Dell'Unto, N., Landeschi, G., Leander Touati, A.-M., Dellepiane, M., Callieri, M., Ferdani, D. (2016). Experiencing Ancient Buildings from a 3D GIS Perspective: a Case Drawn from the Swedish Pompeii Project. *Journal of Archaeological Method and Theory*, 23(1), 73–94.

Doerr, M. (2009). Ontologies for cultural heritage. In *Handbook on Ontologies*, 463-486. Springer Berlin Heidelberg.

Fabiani, F., Grilli, R., Musetti, V. (2016). Verso nuove modalità di gestione e presentazione della documentazione di restauro: SICAR web la piattaforma in rete del Ministero dei Beni e delle Attività Culturali e del Turismo. *"Bollettino Ingegneri", Collegio Degli Ingegneri Della Toscana*, 3, pp. 3–13.

Finat, J., Delgado Del Hoyo, F. J., Martínez García, R., Fernández Martín, J. J., San José Alonso, J. I., Martínez Rubio, J. (2010). Hacia una integración de los Sistemas de Documentación, Información y Gestión del Patrimonio. Resultados y retos. In *Jornadas sobre "Documentación Gráfica del Patrimonio.*

Presente y Futuro" organizadas por el Instituto de Patrimonio Cultural de España, 15-17 November 2010: 164–177. Madrid, IPCE/Ministerio de Cultura.

Gómez González, Ll. (2013). *Estudio y adaptación al PNCPCSXX de los inventarios de arquitectura de España*. Madrid, Instituto del Patrimonio Cultural de España, Ministerio de Educación, Cultura y Deporte.

Gómez González, Ll. (2015). *Inventarios de arquitectura, ingeniería y urbanismo del s. XX en España. Estado de desarrollo por las Comunidades Autónomas*. Patrimonio Cultural de España, (10), 185–193.

Martínez Pino, J. (2012). La gestión del patrimonio histórico artístico en el siglo XIX: fuentes para su documentación. *Tejuelo: Revista de ANABAD*, 12, 10-21.

Myers, D., Dalgity, A., Avramides, I. (2016). The Arches heritage inventory and management system: a platform for the heritage field. *Journal of Cultural Heritage Management and Sustainable Development*, 6(2), 213-224.

Potenziani, M., Callieri, M., Dellepiane, M., Corsini, M., Ponchio, F., Scopigno, R. (2015). 3DHOP: 3D Heritage Online Presenter. *Computers & Graphics*, 52, 129–141.

Salonia, P., Negri, A. (2003). Historical buildings and their decay: data recording, analysing and transferring in an ITC environment. *ISPRS-International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XXXIV(5/W12), 302–306.

San José Alonso, J. I., Finat, J., Pérez-Moneo, J. D., Fernández Martín, J. J. & Martínez Rubio, J. (2009). Information and knowledge systems for integrated models in cultural heritage. *ISPRS-International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences. Proceedings of the 3rd ISPRS International Workshop 3D-ARCH 2009*, XXXVIII-5(W1).

Saygi, G. y Remondino, F. (2013). Management of Architectural Heritage Information in BIM and GIS: State-of-the-Art and Future Perspectives. *International Journal of Heritage in the Digital Era*, 2(4), 695–713.

Schütz, M. (2016). *Potree: Rendering Large Point Clouds in Web Browsers*. Faculty of Informatics at the Vienna University if Technology.

Scopigno, R., Callieri, M., Dellepiane, M., Ponchio, F., Potenziani, M. (2017). Delivering and using 3D models on the web: are we ready?. Virtual *Archaeology Review*, 8(17), 1–9.

Smuts, K. (2015). Sahris: Using the South African heritage register to report, track and monitor heritage crime. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences - ISPRS Archives*, 40(5W7), 395–402.

Soler, F., Torres, J. C., León, A. J., Luzón, M. V. (2012). Design of an Information System for Cultural Heritage. In I. Navazo & G. Patow (Eds.), *CEIG - Spanish Computer Graphics Conference*, pp. 113–122. Jaén, The Eurographics Association.

Soler, F., Melero, F. J., Luzón, M. V. (2017). A complete 3D information system for cultural heritage documentation. *Journal of Cultural Heritage*, 23, 49–57.

Stefani, C., Brunetaud, X., Janvier-Badosa, S., Beck, K., De Luca, L., Al-Mukhtar, M. (2014). Developing a toolkit for mapping and displaying stone alteration on a web-based documentation platform. *Journal of Cultural Heritage*, 15(1), 1–9.

UNESCO. (1972). *Convencion sobre la proteccion del patrimonio mundial, cultural y natural*. World Heritage Comitee

Von Schwerin, J., Richards-Rissetto, H., Remondino, F., Agugiaro, G., Girardi, G. (2013). The MayaArch3D project: A 3D WebGIS for analyzing ancient

DOI: 10.15320/ICONARP.2022.207

architecture and landscapes. *Literary and Linguistic Computing*, 28(4), 736–753.

Resume

Dr. Marta Quintilla-Castán is Assistant professor of the Graphic Expression Area Architect of the School of Engineering and Architecture of the University of Zaragoza (Spain). She combines professional work with research oriented to the application of new media computers for the restitution and dissemination of architectural heritage.

Dr. Luis Agustín-Hernández is Professor at the University School, responsible for the Area of Architectural Graphic Expression and Director of the Department of Architecture at the School of Architecture and Engineering from the University of Zaragoza. He does research work in two complementary lines: Study of the heritage architecture works developed in architecture Mediterranean Gothic in the Crown of Aragon, studies on Mudejar architecture and contemporary architecture. Technology of architectural representation, BIM, Photogrammetry, Scanner Laser, virtual reality and photorealistic.