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MANAGEMENT OF BUILT HERITAGE VIA THE HBIM PROJECT: A CASE STUDY OF FLOORING AND WALL TILING

LA GESTIÓN DEL PATRIMONIO CONSTRUIDO A TRAVÉS DEL PROYECTO HBIM: UN ESTUDIO DE CASO DE PAVIMENTOS Y ALICATADOS

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Abstract:

Building Information Modelling (BIM) is a collaborative system that has been fully developed in the design and management of industries involved in Architecture, Engineering and Construction (AEC) sectors. There are, however, very few studies aimed at managing information models in the field of architectural and cultural heritage interventions. This research therefore proposes an innovative methodology of analysis and treatment of the information based on a representative 3D graphic model of the flooring and wall tiling of a historic building. The objective is to set up a model of graphic information which guarantees the interoperability of the aforementioned information amongst the diverse disciplines intervening in the conservation and restoration process. The Pavillion of Charles V, a Renaissance-characterised building located in outdoor areas of the Alcazar of Seville, Spain, was selected for the study. This work constitutes a project of intervention based on Heritage or Historic Building Information Modelling, called the "HBIM Project".

Key words: HBIM Project, Historic Building Information Modelling, patrimonial information model, photogrammetric restitution, Architectural Archaeology, BIM.

Resumen:

El Modelado de Información para la Construcción (BIM) es un sistema colaborativo que actualmente está plenamente desarrollado en el diseño y la gestión de las industrias involucradas en el sector de la Arquitectura, Ingeniería y Construcción (Architecture, Engineering and Contruction- AEC). En cambio, en el ámbito de las intervenciones en el Patrimonio Cultural y Arquitectónico, son muy pocos los estudios dedicados a gestionar modelos de información. Por ello, esta investigación propone una metodología innovadora de análisis y tratamiento de la información basada en un Modelo gráfico 3D representativo de pavimentos y alicatados de un Edificio Histórico. La finalidad es crear un modelo de información gráfica que garantice la interoperabilidad de dicha información entre las diversas disciplinas que intervienen en el Proceso de Conservación y Rehabilitación Patrimonial. Para el estudio, se ha seleccionado el Cenador de Carlos V (o de la Alcoba); edificio de carácter renacentista perteneciente a los espacios exteriores del Alcázar de Sevilla, España. Este trabajo constituye un proyecto de intervención basado en un modelo de información patrimonial o del edificio histórico, denominado "Proyecto HBIM".

Palabras clave: Proyecto HBIM, Historic Building Information Modelling, modelo de información patrimonial, restitución fotogramétrica, Arquelogía de la Arquitectura, BIM.

1. Introduction

Digital information systems are now the primary tools for scientific research in the field of cultural and architectural heritage management. Meyer *et al.* (2007) proposed a virtual environment implemented by Geographic Information Systems (GIS) for researching in the field of cultural and architectural heritage. In addition, there has been an advance based on the division of a building into parts in the form of box systems conducted via GIS in order to document, catalogue and manage the restoration process. The latest enquiries in systems which are applied to architectural heritage models range from a two-dimensional (2D) GIS system to a 3D-content model for built heritage preservation and management. This is possible thanks to the simplified parametric models that are suitable for industrial elements and those models from modern architecture. Terms reinforcing the concept of Historic Building Information Modelling (hereinafter HBIM) involve the establishment of preventive conservation as a real quotidian need, the exchange of information and the dissemination of knowledge of architectural heritage (Oreni 2013).

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Other lines of research on the subject support City GML as a standard methodology for 3D information storage that is related to architectural heritage (Prieto *et al.* 2012). City GML is an implementation scheme for spatial data exchange. Its objective is to define basic entities through: attributes; 3D model relations; and design principles based on geometric properties and semantics. Although this model does not meet architectural heritage documentary needs, it can be extended with “Core Data Standard for Archaeological Sites and Monuments”.

For the research discussed in this paper, 3D modelling — informed by laser scanning and photogrammetry — is used to develop an efficient and accurate representation of diverse and complex architectonic structures. The potential to use these models to simulate and visualize possible future or past conditions is made possible by Building Information Modelling (hereinafter BIM).

The essence of BIM is to achieve a database of graphic and alphanumeric information where each participative discipline integrates its knowledge in parametric software and adapts to building features in a coordinated manner. Thus, BIM becomes a strategy of collaboration that implies the exchange of contents and transparency between all the actors, thereby creating a teamwork-based culture (Garagnani 2012). Recent research into this approach supports the application of this technology to newly constructed buildings, where owners, builders and installers participate in the functionality of BIM. However, an increasing number of maintenance interfaces and functionalities are now being applied to extant buildings (Volk *et al.* 2014). There are studies in the field of information modelling research that enable virtual reconstruction, through metric plans and documentary evidence, to raise awareness concerning demolished public buildings that belong to lost heritage (Boeykens *et al.* 2012). The recognition of BIM as a technology is due to the multi-disciplinary knowledge base where life-cycle processes, for example operation, renewal and development of the growing inventory of heritage sites are managed (Fai *et al.* 2011). Nevertheless, this technology as a centre for data records for architectural heritage documentation has yet to be fully explored (Fai *et al.* 2013). In this respect, it is to be considered that disciplines such as archaeology, which produces information records as a whole, are expanding since studies into objects are becoming more in depth, and thereby causing systems to be more complex.

One of the main challenges to implementing BIM in the AEC sector has been interoperability with existing information management systems both within individual disciplines and between disciplines. This continues to be an area of active research (Demian and Walters 2013; Grilo and Jardim-Goncalves 2010). It is significant in this context that communication between the diverse professionals involved in architectural heritage is often time even more complex than in the construction industry. Each discipline in the restoration and rehabilitation of historic buildings presents its own peculiarities. Architects, archaeologists, art historians, restorers, and photographers constitute the artistic labour involved in the procedurers of intervention. Participation in this kind of multidisciplinary work requires the establishment of shared hypotheses, data exchange and analyses of results. Nevertheless, major problems arise in the compartmentalisation and duplication of information. It is now widely accepted in the field of architectural heritage that an international standard for information management needs to be established.

The case study presented in this paper is developed within the framework of the precedents discussed above, where a 3D model with data records is created in the audit stage. The audit stage can be defined as the amount of operations carried out to ascertain the nature of a historic building. It also introduces a working hypothesis about the mosaics and tiling areas. This study has been implemented using well established methodologies for stratigraphic analysis as the basis of archaeology and architecture. Following González (2003), the main phases of restoration of monuments — reading, reflection and intervention — the project should be interpreted as the ultimate expression of hypotheses that only subsequent verification will ratify.

A project of intervention — the so-called HBIM Project, which includes an information model for heritage — admits the application of inverse engineering by using parametric objects in order to constitute construction parts. These are created by means of laser scanning and photogrammetric techniques (Dore and Murphy 2014), thereby making it possible to achieve current state diagnosis.

Therefore, the starting point should be a BIM supported by the aforementioned precise modelling techniques (Murphy *et al.* 2009) for the purpose of becoming the core of an intervention project in architectural heritage. This will assist the professionals involved in defining the chronotypological sequence with the characterisation and individualisation of variables in the analysis of facings (Azkarate 2002).

2. Method and construction process of the HBIM Project for flooring and tiling

This project organises information in the HBIM by defining construction elements, filtering data and visualising wall structures. The subject for our case study is the Pavillion of Charles V (Fig. 1). Built in the mid-sixteenth century following the design of Juan Hernandez, it is a quintessential Spanish Renaissance building. Located in the Jardin de la Cruz of the Alcazar of Seville, it is considered an architectural monument of great heritage value and has been listed as a UNESCO Heritage Site since 1987. The Pavillion currently presents buiding pathologies that are the result of deferred maintenance.

Planning the HBIM Project involves the organisation of information through a protocol created simultaneously with the construction of the BIM and both the historical and the physical-constructional analysis of the Pavillion.

Figure 1: South-west perspective of the Pavilion in the HBIM Project.

In this first stage, information related to geometry, polychromies, construction methods, and deferred maintenance are gathered together along with those elements that are the focus of our study — flooring and tiling. As a second step, all elements are organised into categories and inserted into the model. ArchiCAD offers an array of functions to define building elements and provides a substantial library of parametric objects and materials. This BIM software works with a series of layers related to a construction category, but it is necessary to establish new layers depending on the historic building analyses so that elements identified in an intervention can be assembled in the modelling process. These layers serve as simple containers of elements grouped by characteristics including dimensions, materials and function in the building. However, it is occasionally necessary to sort these elements within the group by their spatial location or detected particularities. In this way, the classification into categories (typology, structural function, position, and rehabilitation status) of every element displayed in the model contributes to the HBIM. Subsequent to this process, the identification of each parametric object is carried out. A characteristic identifier (ID) related to the classified construction parts is applied. The purpose of ths identifier is to identify and cluster the elements specific to each disciplines involved in the restoration process and to facilitate the represention in these elements in discipline specific drawings.

A filtering process is required to display information from the model in stages depicting the temporal and constructional evolution of the building. This process is conducted using specific tools from ArchiCAD software that support graphic data exchange between the diverse professionals that comprise the multidisciplinary work team.

The flow chart in Figure 2 outlines the process for developing an advanced HBIM. This involves two distinct phases. First, a survey for gathering 3D data using laser scanning and photogrammetry (Murphy *et al.* 2009). Second, the development of a building information model for the management of architectural heritage. The main proposal of this research sets three action levels: the aforementioned survey in order to adjust the images to the model by means of photogrammetric rectification; the identification and cataloguing of irregular pieces; and finally the management of information.

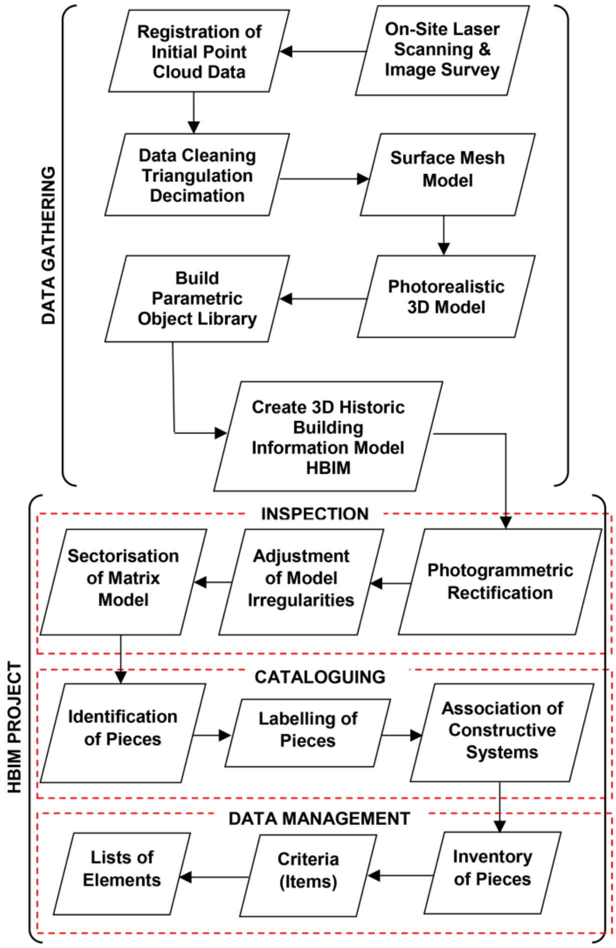


Figure 2: Proposal of the HBIM Project.

2.1. Modelling with parametric elements in the HBIM Project

Currently, BIM software includes design tools to model elements from construction systems, such us slabs, pillars, joists and roofs. These elements are developed as parametric objects of architectonic pieces, standardised profiles and parts from already patented technological systems. BIM developed for use in the Architecture, Engineering and Construction (AEC) industry are optimized for new buildings. While the modelling procedure is the same in the case of an historic building, significant challenges arise when the model is built with construction elements defined according to historical data. In these cases, it is necessary to adapt the software to use traditional construction techniques and materials. This involves the exploration historical-constructional stages, where Geometric Descriptive Language (GDL) libraries are used to create a primitive model by following an ideal geometry. Parameters are subsequently modified as the exploration of pathologies progresses. Recent studies highlight the capacity to create a historical framework that contains an extensive parametric library of architectonic features based on manuscripts of architecture (Murphy *et al.* 2013). This work represents an advance in the generation of architectural intervention models, where GDL objects facilitate accurate parametric modelling of traditional materials and methods of construction within a BIM environment.

2.1.1. Ortho-rectification for surface mapping

The use of ortho-rectified photography as an effective tool for the documentation of cultural heritage is studied well established in current scientific literature (e.g. McCarthy 2014).

For the HBIM Project, information is structured in accordance with the logical restoration process in order to facilitate the restitution procedure and to prevent errors. To this end, a new, fixed and considerably long focal length — greater than the depth of the Pavillion's loggias — was needed. It was decided to photograph consecutively around the perimeter of the building and to avoid the columns. Photographs were taken perpendicularly to the tiling using a single lens reflex (SLR) digital camera Canon EOS 500D with an 18-55 mm lens, exposure value f/3.5-5.6 and 18 mm focal length.

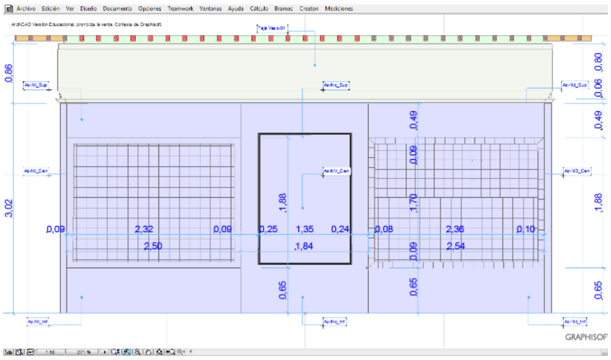


Figure 3: Sectorisation of tiling areas in the northern façade of the Pavilion.

Borders and changes in decorations are delimited later by specifying their coordinates to facilitate the characterisation of the walls. Data transfer is then carried out by fragmenting the surface of the wall in the model, classifying it in functional sectors and identifying each of the pieces of tessellation (Figs. 3 and 4).

These pieces are shown and identified with labels in each dimensioned sector of the elevation by utilising the <Morph> tool in ArchiCAD.

2.1.2. Mapping and fragmenting of the HBIM Project

In order to map the tiled surfaces of the Paviillion, ortho-images are associated with the 'wall finish' layer of the model. A unique texture is created for each sector of tiled wall — or decorative element — over the surface and is included in the surface library of the ArchiCAD software. This method allows for a photo-realistic mapping of the tiles and friezes. This allows elements to be explored more easily on the surface of the wall: ashlar and brick bonding, tiling, friezes and decorative details. This facilitates the analysis of peculiarities and historical characteristics of materials and allows for a typological identification of each piece before undertaking their reinstatement.

The borders of individual tiles are delineated utilising the <Pencil> tool from the Editing Palette. The ortho-image associated with the facing <Morph> of the walls is used as a template. Once the vector grid of those pieces is concluded, tiles are selected in terms of their typology to obtain new isolated shapes (tile and frieze) from the area, which is then fragmented (Fig. 5).

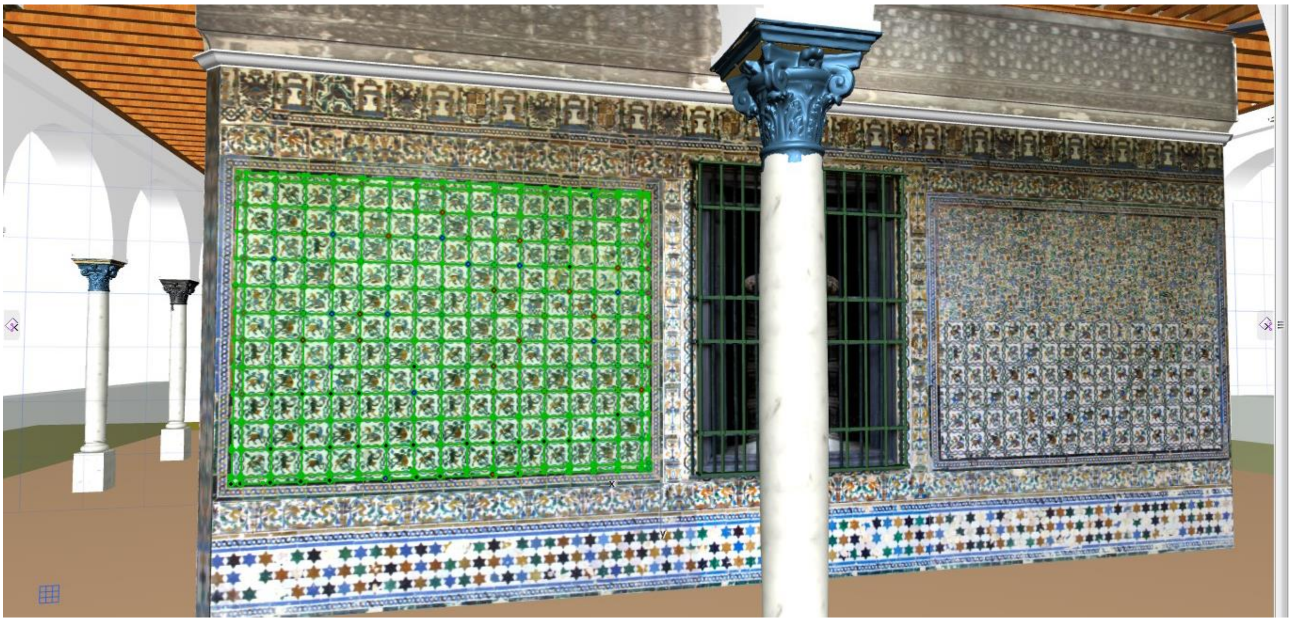


Figure 4: Visualisation of the model in the HBIM Project.

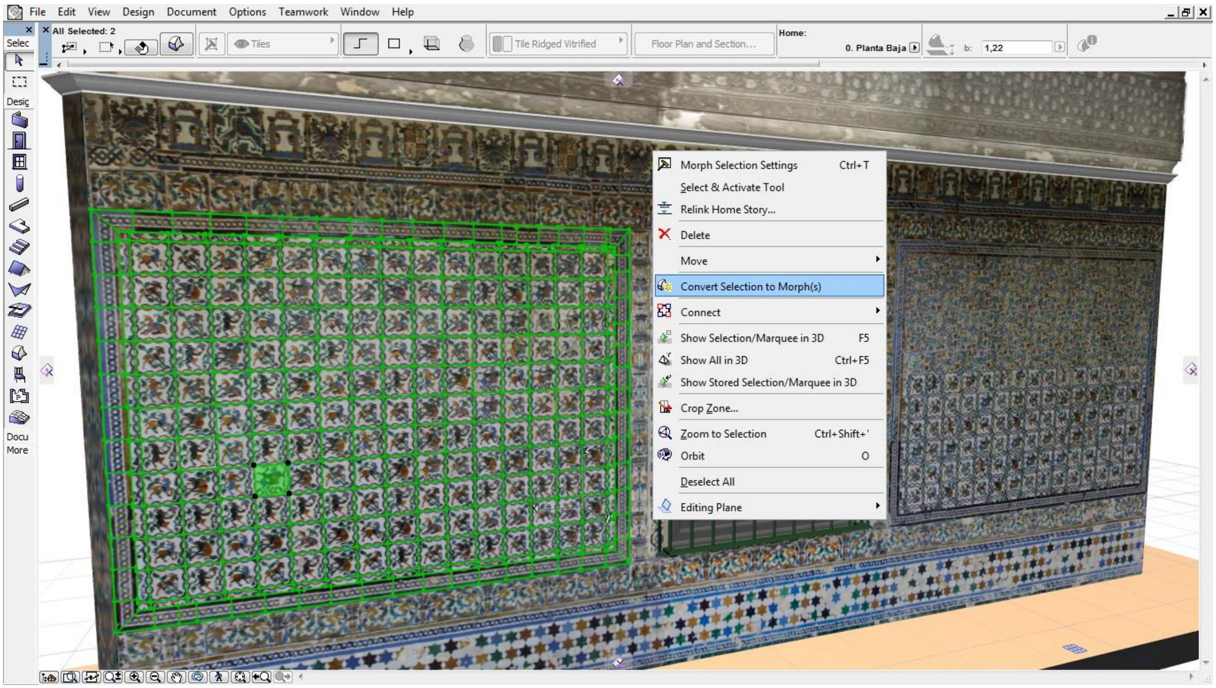


Figure 5: Sub-elements with the same typology are converted into isolated elements.

This methodology enables the geometry of the wall to be accurately recorded. However, it should be taken into account that ceramic tiles from the 16th century are often damaged. In the specific case of the Pavillion, audited pathologies show a noticeable irregular alignment, with signs of continuous repairs. As a result, tracing each individual tile (using the <Wall> tool in ArchiCAD) would have been a tiresome and imprecise task. Instead, we used a specific API in ArchiCAD to expedite the tracing and automatically create a normalized vector grid (with its original ID: *Az-NI_Cen*).

After this task, the identification process and piece labelling with identifiers was performed. In the case of the centre-left facing in the northern façade, this was accomplished by using the names of animals and mythological characters that had been depicted: horse, centaur, wolf, monkey, satyr and unicorn.

It is important to note that the pieces (as isolated elements) maintain the image of the corresponding tile within the matrix (Fig. 6).

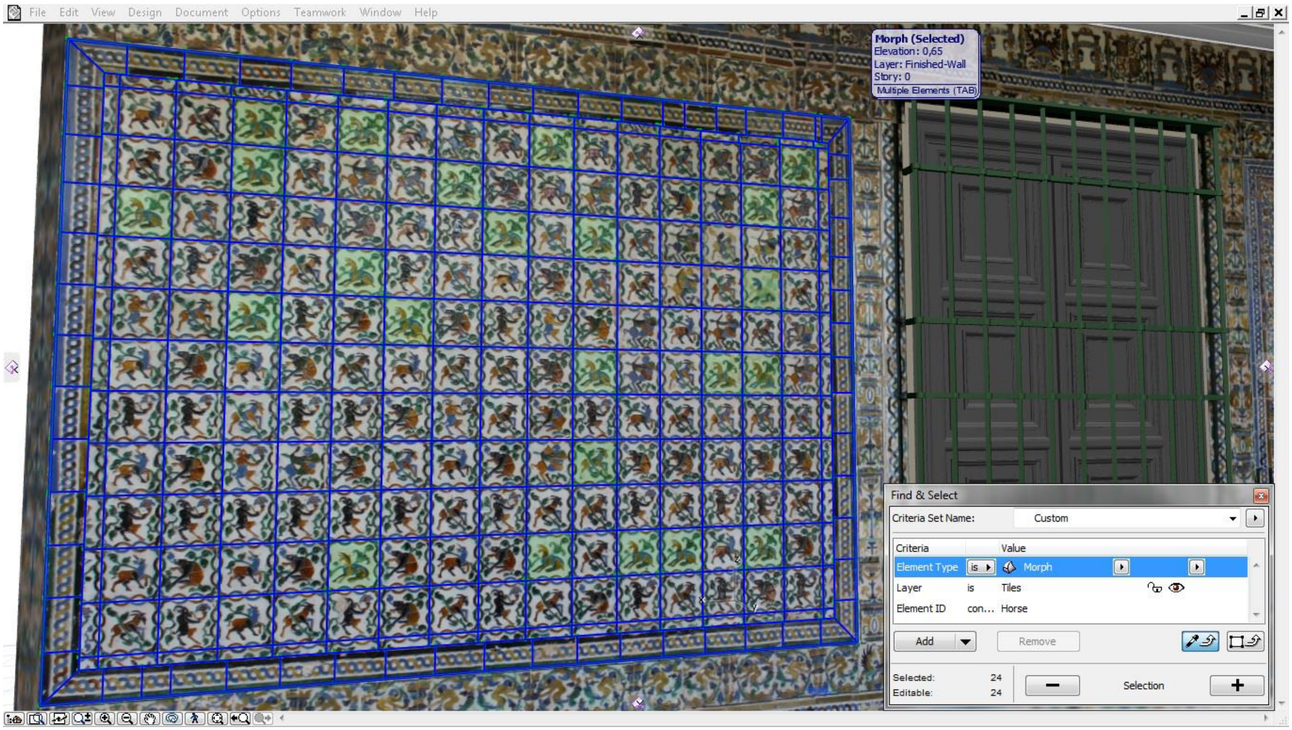


Figure 6: Identification of pieces in the central left-hand sector of the facing in the northern façade.

2.1.3. Identification of pieces for floor restoration

The extraordinary composition of mosaics and clay tiles, both delimited by ceramic borders and inserts forming equidistant squares and radial shapes, presented pathologies caused by the presence of lime in the water and the abrasion linked to the cladding. The pieces are identified according to their geometric shape: circle, heart, star, flower, octagon, oval, pentagon, rhombus, oval rhombus and triangle. The procedure of delimiting and identifying pieces is similar to that used in wall tiling. The first step involved the conversion of the element <Slab> (the floor of the room) into tool <Morph> in order to connect it to the ortho-image from the floor (Fig.7).

Figure 7: Top view of the floor mapped with multiple ortho-rectificated shots. The Pavillion of Charles V.

Here, following the same work method, the boundaries of floor tiles, friezes and central sectors containing inserts (ceramic rhombic and rectangular pieces) are delineated using the <Pencil> tool from the Editing Palette within the <Morph> tool, but without dividing the floor into parts (Fig. 8). Once this has been performed, the vector grid is superimposed onto the image of the floor, which is comprised of various closed geometric shapes.

Only a single ensemble is hitherto constituted; here, however, the division of the matrix into <Morph> sub-elements is carried out in order to identify pieces by individual typologies. Floor tiles, perimeter friezes, rhombus mosaics and the vertex pieces in the central area are all differentiated. Finally, clay tiles are isolated from the rest of the floor and contain their respective ortho-image adjusted without undertaking other operations (Fig. 9).

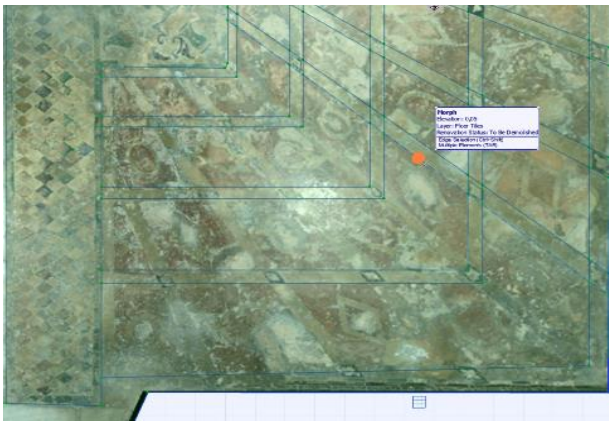


Figure 8: Demarcation of floor tiles and friezes in the room of the Pavillion.

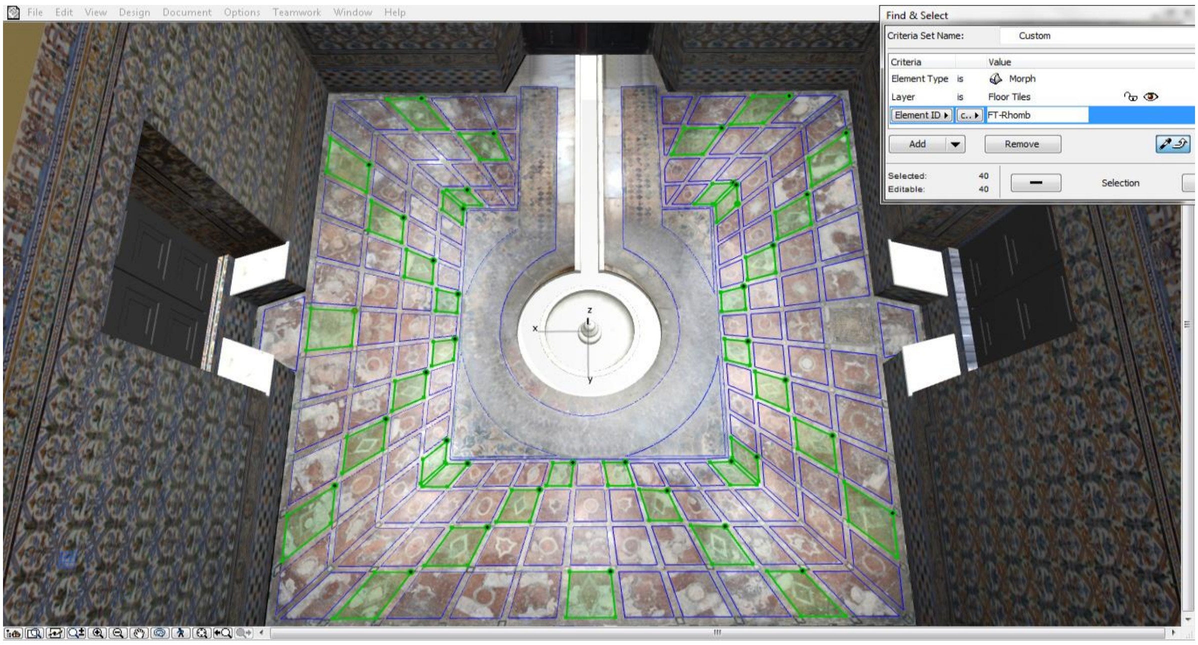


Figure 9: Floor sectorised into typologies depending on its filtering: Shape type, Floor Tiles layer, ID of the element.

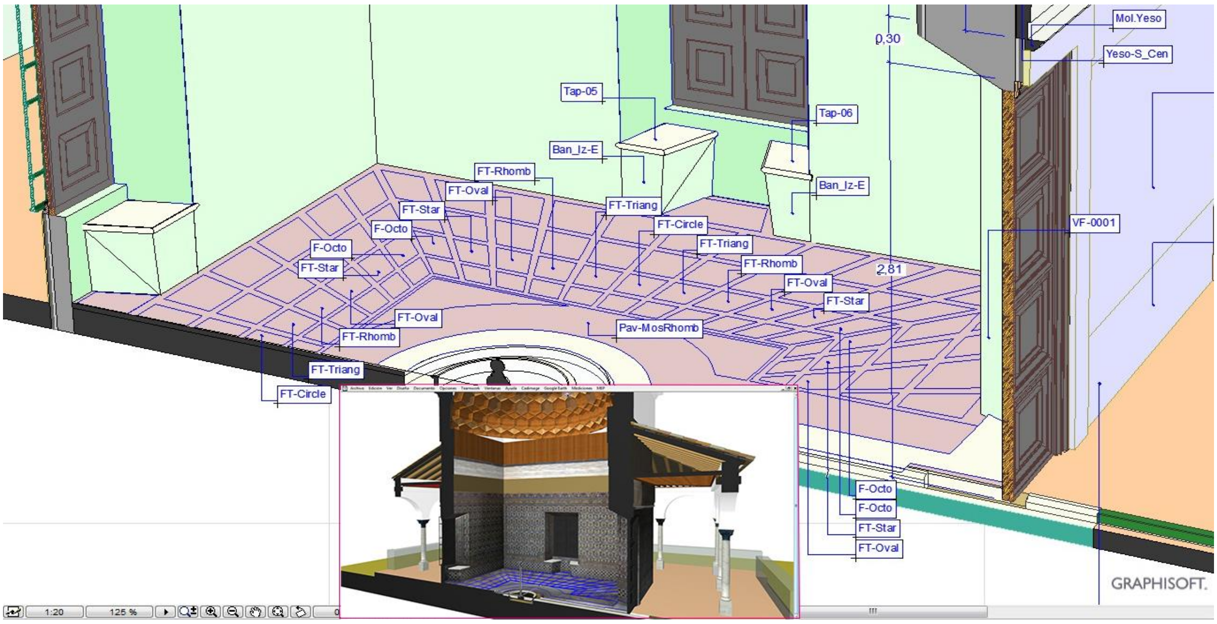


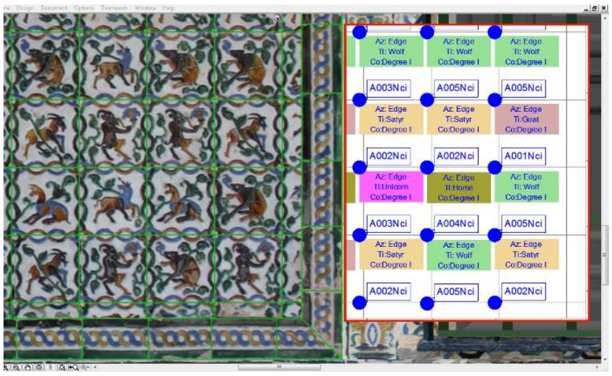
Figure 10: a. Session model with flooring once outlined. b. Floor sectorised by typologies: Shape, Floor Tiles layer, element's ID.

The ensuing step is to classify each floor tile with its own ID and a label in terms of the motif it displays. For instance, *FT-Oval* ID is used for the piece *Oval*. When the tiles are sorted according to their kind, they can be added the new layer created (Fig. 10).

2.1.4. Labelling of pieces in restoration works

The 2D plan and elevation projections are produced once all of the pieces from the floor tiles, friezes and the rest of the decorative fragments from the floor have been identified. Labels function as text blocks or optional symbols linked to construction parts and 2D patterns. In general, the ID is shown in the label as the basic identification of all elements of the HBIM Project, but there are cases in which information in plans must be improved by adding more data to ease the labour of researchers in restoration. Various types of labels are utilised in the case of the Pavillion of Charles V. For instance, *Az-ND_Cen* indicates the tiling of the northern facing, centrally located in the right-hand sector.

Each piece of tile is individually labelled in this process. The first label specifies the position of the piece with respect to a relative reference point (eg. lower left) in order to compose an array of coordinates prior to dismantling the tiles for off-site restoration. Additional information on each piece appears in what we have termed the "second label". This includes typology, motif and preservation status. It also shows identification for its classification. For example, *A001Nci* for the ridged tile with the motif *Goat*, located in the upper left-hand side of the central sector of the northern facade (Fig. 11). This advanced label is called the Label Multileader (http://www.masterscript.nl/), and is associated with each tile and possesses two signatures, one for categorisation and another for information from the audit.



(a) (b)

Figure 11: Partial elevation of the tiling sector Az-NI_Cen: a) Texture; b) Labels for identification.

2.1.5. Association of materials and construction systems

In order to identify a specific element within a larger area under study, a construction material from the ArchiCAD database is linked to the piece. The software permits access to a catalogue of physical properties such as thermal conductivity, density and heat capacity. It is then subdivided into construction typologies selected from standard or custom options.

Data related to materiality, geometry, assembly, and other physical properties is integrated in the BIM. This data can be consulted by all professionals working on the project.

Diverse elements (tiles, friezes and mosaics) are present in the facing in this study. In order to identify geometric alterations in all pieces of the same material, physical properties, and identical production system, the structure and external appearance were linked to a vector grid which is associated with the shape and the distinctive texture of each typology of pieces. Figure 12 shows the edition of a construction material of a *Ridged Vitrified Tile*.

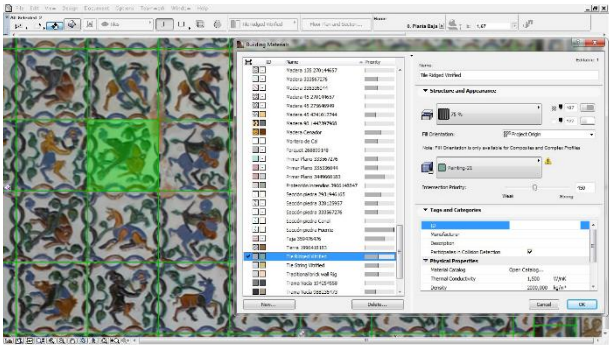


Figure 12: Edition of the Ridged Vitrified Tile.

2.1.6. Data management and lists of elements

Once the graphic procedures of sectorisation, classification and identification of tiling and flooring have been achieved, the databases can be composed. A basic criterion that defines the information is established so that data can be filtered and viewed. The sorting of elements by their interior or exterior position within the model (Fig. 13) and by their rehabilitation status among other standards is necessary for their classification by families in the model. The inserted pieces are identified in tiling and flooring and then a register of stratigraphic units is created (already identified in the archaeological study). It is also possible to list present pathologies and deformations in certain elements of the Pavilion.

Finally, charts obtained for the inventory and exploration of elements of this HBIM Project display rows where pieces are identified by types. All varieties of tiles and friezes are inventoried in the northern exterior facing of the building (Fig. 14).

In the case of the floor, the inventory sheet holds information on 183 floor tiles, making a total area of 26.57 m^2. The grid composed of perimeter friezes as a group and is identified as the *Pav-Frieze* unit, makes 8.90 m^2. Other data of interest for the completion of the sheet by the restoration specialist appears in the rest of the columns, and includes chronology, dating, conservation status and atmospheric, biological, mechanical and chemical aggression (Figs. 15 and 16).

Figure 13: Section of the model of the Pavillion of Charles V in the HBIM project.

LRE-02(R) INVENTORY SHEET OF TILES

	ID	Quantity	Position	Element Classification	Renovation Status	Building Material	Dating	Chronology	Dimensions Item	Dimensions Module
Layer Frieze										
	Cen-string	64	Exterior	Covering	Existing	Tile Ridged Vitrified	S. XVI			
		64								
Layer Tiles										
	Centaur	11	Exterior	Covering	Existing	Tile Ridged Vitrified	S. XVI			
	Centaur	3	Exterior	Covering	To Be Demolished	Tile Ridged Vitrified	S. XVI			
	Goat	5	Exterior	Covering	To Be Demolished	Tile Ridged Vitrified	S. XVI			
	Goat	37	Exterior	Covering	Existing	Tile Ridged Vitrified	S. XVI			
	Horse	3	Exterior	Covering	To Be Demolished	Tile Ridged Vitrified	S. XVI			
	Horse	20	Exterior	Covering	Existing	Tile Ridged Vitrified	S. XVI			
	Monkey	2	Exterior	Covering	To Be Demolished	Tile Ridged Vitrified	S. XVI			
	Monkey	15	Exterior	Covering	Existing	Tile Ridged Vitrified	S. XVI			
	Satyr	33	Exterior	Covering	Existing	Tile Ridged Vitrified	S. XVI			
	Strip-Az	1	Exterior	Covering	To Be Demolished	Tile Ridged Vitrified	S. XVI			
	Strip-Az	55	Exterior	Covering	Existing	Tile Ridged Vitrified	S. XVI			
	Unicorn	21	Exterior	Covering	Existing	Tile Ridged Vitrified	S. XVI			
	Wolf	15	Exterior	Covering	Existing	Tile Ridged Vitrified	S. XVI			
		221								
		285								

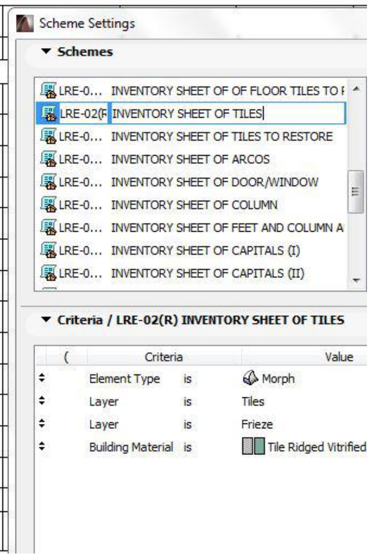


Figure 14: Visualisation of the Inventory Sheet of Tiles from northern exterior facing.

LRE-01(R) INVENTORY SHEET OF FLOOR TILES TO RESTORE

	ID	Quantity	Position	Element Classification	Renovation Status	Building Material	Surface Area	Dating	Conservation status	Atmospheric agent	Biological agent	Mechanical agent	Chemical agent
Layer Floor Tiles													
	F-Laber	1	Interior	Footing	To Be Demolished	Ceramic Floor Tiles Mosaic	0,20	S. XVI					
	F-Octo	9	Interior	Footing	To Be Demolished	Ceramic Floor Tiles Mosaic	0,59	S. XVI					
	FT-Circle	18	Interior	Footing	To Be Demolished	Ceramic Floor Tiles Mosaic	2,22	S. XVI					
	FT-Flower	4	Interior	Footing	To Be Demolished	Ceramic Floor Tiles Mosaic	0,36	S. XVI					
	FT-Heart	4	Interior	Footing	To Be Demolished	Ceramic Floor Tiles Mosaic	0,64	S. XVI					
	FT-Oval	31	Interior	Footing	To Be Demolished	Ceramic Floor Tiles Mosaic	2,95	S. XVI					
	FT-Penta	9	Interior	Footing	To Be Demolished	Ceramic Floor Tiles Mosaic	0,38	S. XVI					
	FT-Rhomb	31	Interior	Footing	To Be Demolished	Ceramic Floor Tiles Mosaic	3,30	S. XVI					
	FT-RhombOval	9	Interior	Footing	To Be Demolished	Ceramic Floor Tiles Mosaic	0,38	S. XVI					
	FT-Star	31	Interior	Footing	To Be Demolished	Ceramic Floor Tiles Mosaic	2,79	S. XVI					
	FT-Triang	28	Interior	Footing	To Be Demolished	Ceramic Floor Tiles Mosaic	2,79	S. XVI					
	Pav-Canal	1	Interior	Footing	To Be Demolished	Ceramic Floor Tiles Mosaic	1,86	S. XVI					
	Pav-MosRhomb	2	Interior	Footing	To Be Demolished	Ceramic Floor Tiles Mosaic	4,21	S. XVI					
	Pav-Quad NE	1	Interior	Footing	To Be Demolished	Ceramic Floor Tiles Mosaic	0,32	S. XVI					
	Pav-Quad NW	1	Interior	Footing	To Be Demolished	Ceramic Floor Tiles Mosaic	0,30	S. XVI					
	Pav-Quad SE	1	Interior	Footing	To Be Demolished	Ceramic Floor Tiles Mosaic	0,25	S. XVI					
	Pav-Quad SW	1	Interior	Footing	To Be Demolished	Ceramic Floor Tiles Mosaic	0,25	S. XVI					
		182											
Layer Pavement - Borders													
	Pav-Friezes	1	Interior	Footing	To Be Demolished	Ceramic Floor Tiles Mosaic	8,90	S. XVI					
		1											
		183											

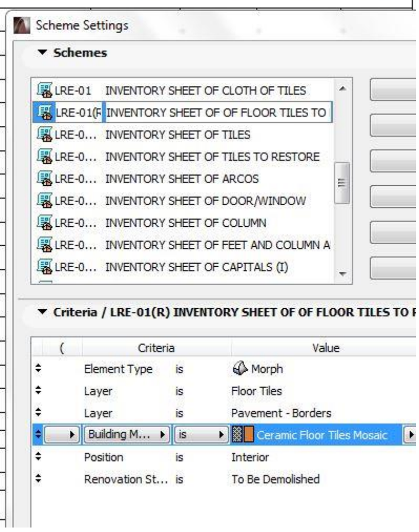


Figure 15: Inventory chart of the pieces in the interior flooring.

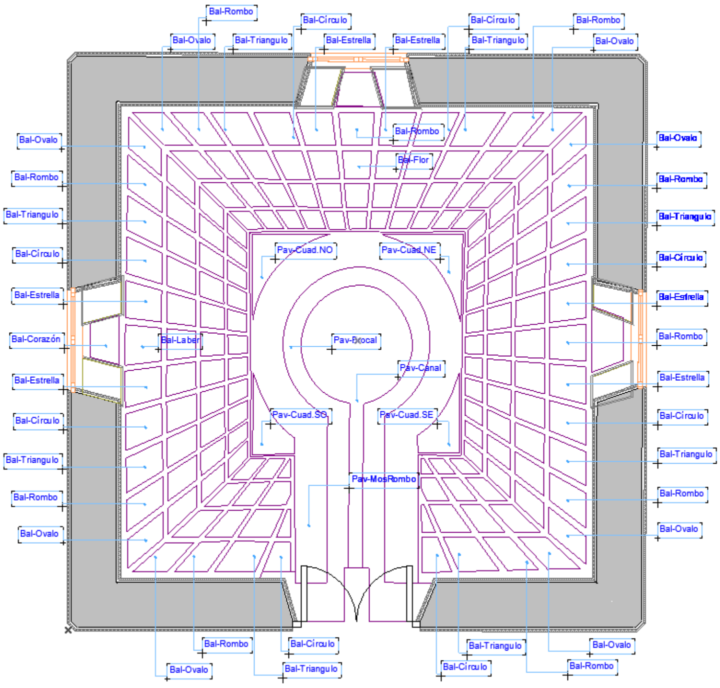


Figure 16: Vector Plant ID for identification of floor tiles extracted from the HBIM Project of the Pavillion of Charles V.

3. Discussion of results

The outcome of this research demonstrates that BIM — in this case ArchiCAD by Graphisoft — has tools available to model complex geometries that are typical of architectural heritage. These tools are similar to software for 3D modelling such as 3DStudio Max, Cinema 4D, and Rhinoceros.

The modelling process still requires significant effort. However this can be reduced with the utilisation of diverse techniques for both complex construction parts and decorative pieces. For ceramic tiles with decorative motifs, and very low relief, orthophotography contributes greatly to the virtual reconstruction. In order to catalogue floor and wall tiles, it is sufficient to know the information provided by an image (number of pieces, motif and conservation status) and their dimensions obtained by means of traditional measurement methods.

3D laser and optic scanning are rapid and precise tools for capturing architectural geometry. This data can be used to great to create paramentric objects for BIM with a high level of development. However, existing BIM software is often limited in being able to manage the number of highly detailed parametric objects typically associated with a heritage building. From our experience, the main impediment lies in the file size of scanned 3D objects. Consequently, a simplification process applied to the number of polygons in meshes is necessary. The quantity of graphic data to be displayed simultaneously needs to be reduced significantly without a significant loss in the level of detail.

Our research confirms that BIM is an effective method for generating a graphic model of parametric entities and managing the data related to those entities. BIM eases the management of the graphic and alphanumeric data, thereby obviating the need to utilise other external platforms. The characterisation conducted of walls and floors to identify pieces for an analysis or restoration can be interrelated with record layouts designed for each specialist. These record layouts are configurable according to each discipline by including items essential for the professionals involved. Each change in the characteristics of a construction part within the BIM is immediately displayed in the record layout.

In addition, an accurate inventory classified by construction typologies is completed with the geometric data and intrinsic properties of the elements in the information model, such as arches, carpentry work, columns and beams of the structure of the loggias, and the coffered ceiling.

Finally, the HBIM Project incorporates lists of elements so that the Bill of Quantities can be obtained. This document can either be linked to cost databases in the same software or be exported to time and cost management programmes (4D and 5D, respectively) in order to obtain the restoration budget.

Although, in principle, the creation of the model is conducted by specialists in BIM software, non-qualified users are able to implement data records on the model. In this sense, any user is capable of including historical information, the materials employed, or their conservation status. Thus, the cataloguing of elements as objects with IDs allows the automatic identification of the pieces for cladding and flooring, and therefore eases the data exchange process.

Furthermore, it is worth mentioning that the global measurements of the building were contrasted with the information derived from the 3D laser scanning technique in order to achieve an accurate BIM model. In the present case study, the modelling methodology is based on references to the three-dimensional point cloud, so that the construction system of the building is correctly represented.

4. Conclusions

This research work highlights the potential of BIM platforms in data records for built heritage. One of the factors contributing towards the development and advances in this field is the increase in efficiency and reliability of data gathering by utilising 3D modelling techniques appropriate for the building sector, whereby this data gathering is based on a precise definition of external and proportional characteristics via photogrammetry.

The use of applications that include parametric entities (GDL) has become the turning point in the attainment of graphic documentation and the management of intrinsic data essential for the creation of specific lists of information, which are aimed at cataloguing the analysed elements. Not only data within their defining parameters will be available in the building information model for the professional intervening, but also for other researchers who may need access to it throughout the life cycle of the building.

In addition to the archaeologist, the restorer demands exhaustive identification of all floor and wall tiles so that they can be analysed, compared and classified before the restoration. Components of parametric entities in ArchiCAD software (such as Wall, Slab, Pillar, Joist and Roof) are transformed into more flexible units (Morph) to subsequently subdivide them into pieces embedded in the canvas under study. These elements contain explicit properties of the construction parts analysed, for instance wall tiles, borders, floor tiles and pieces of tessellation. The ortho-rectification of images facilitates the analysis of deteriorated tile cladding and flooring. When this analysis is combined with the mapping technique applied to already modelled elements (walls, floors and roofs, etc.), a continuous and immediate exploration of data from the model is performed.

The BIM system generates a graphic model of parametric objects that enables the refined systematisation and efficient management of the data gathered. This procedure constitutes the basis of the HBIM Project (Historic Building Information Modelling Project) as the appropriate platform for archaeologists, architects, historians and restorers. By these means, this work takes advantage of these factors of new technologies in order to establish a model of identification and registration of pieces and units from tiling and flooring in archaeological and architectural heritage. For its part, the catalogue of materials in the HBIM Project must be continuously supplemented with common construction typologies in the heritage under study and the building peculiarities corresponding to the specific area or era. Furthermore, certain aspects need to be solved in the future, for example the interdisciplinarity and permeability of information in rehabilitation tasks and the identification of control centres, which is not necessary in newly-erected buildings. The future aim of the HBIM Project is clearly set: to establish mechanisms for sharing knowledge and learning BIM platforms between academics and professionals of the sector of built heritage. Archaeologists, architects and historians need to comprehend the versatility of virtual technology and its application to the aforementioned rehabilitation in order to ease the interdisciplinary management of information pertaining to each field.

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