State of the Art of HBIM to Develop the HBIM of the HeritageCare Project

Aurélie Talon, Clémence Cauvin-Hardy, Alaa Chateauneuf

State of the Art of HBIM to Develop the HBIM of the HeritageCare Project

Aurélie TALON, Clémence CAUVIN, Alaa CHATEAUNEUF
Clermont Auvergne University – Institut Pascal UMR 6602
aurelie.talon@uca.fr - clemence.cauvin@uca.fr - alaa.chateauneuf@uca.fr

Abstract

The European project HeritageCare aims to develop a methodology to help managers preserve historic monuments. The methodology developed integrates the advantages of HBIM (Historical Building Information Modelling): 3D visualization, grouping of information (history, diagnostics, videos, etc.) under the same object, help with monitoring of maintenance, help with the planning of works, etc. This article develops in a first part the state of the art on the HBIM and its use: realization of numerical model (tools and database of objects), help with the maintenance, identification of the risks associated with the realization of the works. The second part is devoted to the presentation of the HeritageCare project: context and challenges, content and development of the HBIM part.

Introduction

The HeritageCare project aims to help preserve historic monuments (classified and inventoried) by developing a diagnostic methodology based on BIM. This methodology is intended for owners of historic monuments and is interested in movable and immovable objects; it supports the missions of the DRAC. Outputs of this methodology will be: a regular diagnosis (visual and instrumented) of the state of their monument, recommendations in terms of routine maintenance and work to be undertaken, a management tool for the status of their monument.
This paper presents a state of the art of BIM applications that can be useful for the project developed, namely: HBIM (Heritage Building Information Modeling), risk analysis and maintenance methods. In a second step, the context of the project, the different levels of management planned and the development of HBIM proposed will be presented.

I. State of the art

The problems of preservation of historic monuments and the different management policies of these monuments are described by F. Choay (1996, 2009) and J.P.Thibault (2009).

Murphy et al (2013) define Historic Building Information Modeling (HBIM) as a library of parametric objects based on historic architectural data, in addition to a mapping system for plotting the library objects onto laser scan survey data.

D. Littlefield (2017) proposes, in the following table, a comparison between the contributions and expectations of BIM and HBIM. What is retained for the HeritageCare project is that the digital model must represent the building as it is built, that it must be able to contain all the information useful for its maintenance, including the identification of all defects (qualitatively and quantitatively).

BIM	*HBIM*
captures the building as it is intended to be	captures the building as it is
a resource and test of a structure yet to be constructed	a resource describing a building which has already been constructed
a resource which ensures a new structure conforms to codes and other parameters	a "non-judgmental" resource describing an inherited structure which will inevitably deviate from the ideal
a design, construction, coordination and FM tool	a tool which may record a structure prior to its loss or damage
the known – the "idea" of the intended structure will never be more complete	will embody much of the unknown, including competing and evolving ideas
off-site – assembled to predict how a site will perform once changed	on-site – a response to the site as found
ambition of exactness, predictability, perfection	makes room for imperfection, the accident, the undersigned, the unauthorised
looking, testing	noticing, narrative
singular	plural
integrated	layered
definitive	interpreted
enables site as designed to match site as built	enables comparison between site as designed, site as found and site as imagined
directed	negotiated
ownership is defined	ownership is loose

Table 1. Comparison of BIM and HBIM (Littlefield, 2017)

Counsell et al. (2003) illustrates the different information that is succinct to be included in a HBIM. All of this information is available in France, but generally in paper form or dispersed in different databases. The interest of HBIM is then to bring together all the information useful to all stakeholders in the maintenance of historic monuments.

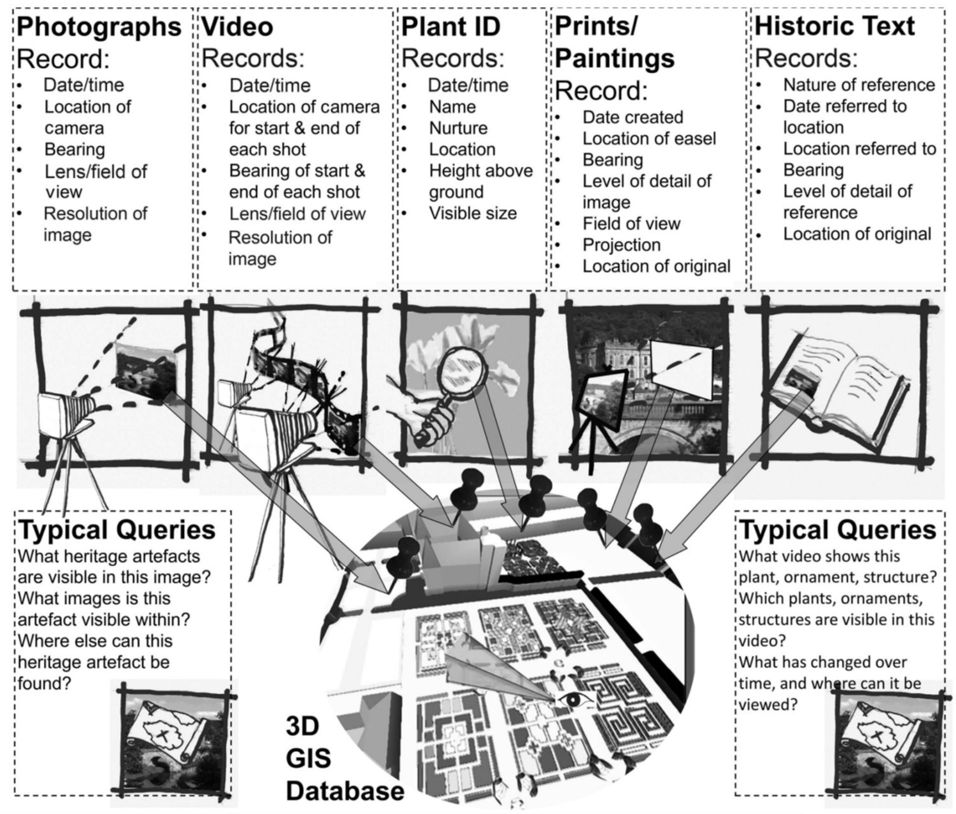

Figure 1. Different kind of information included in HBIM (Counsell et al., 2003)

According to Sabry Hegazi (2017), HBIM can be an important tool in managing information for a group of buildings and sites, as it provides these benefits:

- urban documentation in order to produce accurate land use,
- demographic maps creation as output to monitor large-scale sites and heritage cities,
- monitoring of urban growth by comparing satellite images,
- coverage of historic sites documentation by an infinite number of accurate photos that can be produced by different satellites at the same time,
- utilizing a variation of ultrasonic waves and frequencies to document invisible sites and reveal undiscovered desert heritage districts,
- saving documentation process time and money as well as human resources,
- enabling compatible documentation data for large sites in good quality.

In this section, we will successively discuss the state of the art relating to Heritage Building Information Modeling (HBIM), the risk analysis associating BIM and the maintenance methods using BIM.

I.1. State of the art of HBIM

HBIM papers can be divided into three categories: those dealing with measuring equipment to create a digital model, those relating to object libraries and those considering an approach to the preservation of historic monuments.

The problem for the HeritageCare project is how to obtain the 3D geometry of the works (what hardware, what software?), How to associate the information gathered during the preliminary studies (environment, construction and reconstruction phases, degradations, etc.)., how to use this model to define and program maintenance operations ?

In terms of helping to create digital mock-ups, Helena Rua (Rua and Gil, 2014) explains the approach taken to model a historical monument that is difficult to access. The proposed approach is summarized in the following figure. This approach uses geolocation, a library of objects and digitization.

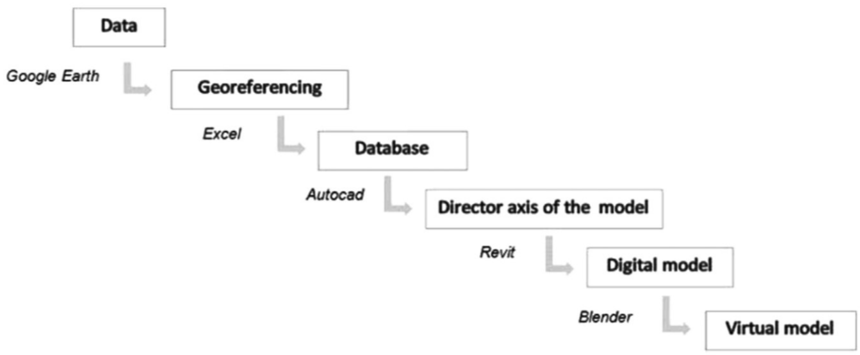

Figure 2. Approach to create a virtual model of historical monument (Rua and Gil, 2014)

These authors also propose a comparison of software used to model historic buildings. This comparison is detailed in the following table.

Modelling characteristics			
	AutoCAD	Revit	Blender
2D	Direct drawing	Indirect drawing: only after 3D modelling is possible to obtain 2D drawings	Direct drawing
3D	Modelling solid shapes based on Boolean operations	Objects defined with its own characteristics ('filled' and 'void' modelling families)	"Epidermal" design tool (more applicable to highly undefined design stages)
Visualization	Allows making renders and movies with some quality	Materials predefined families; appropriate for rendering	High-quality renders and movies
Particularities	– Not suitable for sketching or for free-form modelling – Not suitable for real-time visualization. – High potential to be used in modelling/ construction (technical drawing) – High potential for programming languages (e.g. VisualScheme) and interaction with others software (e.g. Excel) – Higher level of complexity elements (parametric models and associative geometry) – Programming requires redoing all geometry from the beginning, whenever necessary to correct the value of a parameter	– Obscure modelling because of the lack of Boolean operations (only subtraction is possible) – There is no way of knowing which restrictions have already been applied – Lack of abstraction. Method is based on technical drawings, depending on orthogonal projections (views) – Easy and quick way to create models of associative and parametric geometries (but with some limitations in complex geometries) – Schedules linked to elements enable both real-time visualization and correction of the model parameters	– Free and 'light' open source software (portable in a pen-disk) – Game engine integrated (possibility of real-time interaction with the model) – Conversion for another format is possible with eventual loss of quality – Suitable for real-time visualization and rapid prototyping

Table 2. Comparison of software used to model historic buildings (Rua & Gil, 2014)

Ahmad Kaik (2017) also proposes a digital mockup approach based on a laser survey. Once the images are captured and processed, they are assembled to create the digital model. This approach, which also relies on an object library, is specified in the following figure.

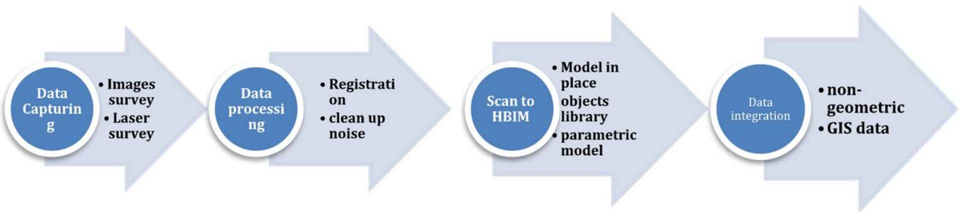

Figure 3. Approach to create a digital model of historical monument based on a laser survey (Kaik, 2017)

Ankit Bhatla et al. (2012) presents a comparison of the different measurement techniques for creating a digital model of a historic monument. This comparison is detailed in the following table. Four techniques are compared: photogrammetry, videogrammetry, 3D camera and laser scanner.

	Photogrammetry	Videogrammetry	3D camera ranging	Laser scanning
Automation of spatial data retrieval	Manual/semi-automated	Automated (limited to non uniform texture regions)	Automated	Automated
Spatial data accuracy	Accurate	Accurate	Not as accurate as photogrammetry and videogrammetry	Most accurate
Spatial data resolution	Low	High	Low	High
Equipment cost	Low (hundreds)	Low	Affordable	High (thousands)
Equipment portability	Lightweight	Lightweight	Portable	Non-portable
Spatial data speed	Non real time retrieval	Real time retrieval	Ream time retrieval	Non real time retrieval
Range distance	Medium	Medium	Short range	Long range
Operation time	Sensitive to light	Sensitive to light	Operates day and night	Operates day and night

Table 3. Comparison of technics to pick up on site geometric information (Bhatla et al., 2012)

Livio de Luca (2009) synthesizes in a reference work, the research work carried out by the MAP laboratory (Models and simulations for Architecture and Heritage) for more than 20 years on the theme of architectural photomodelling.

Concerning object libraries, Ramona Quattrini and Eleonora Baleani (2015) propose a semantic decomposition of elements based on a case study of historical monument, Villa Thiene in Cicogna. The result of this decomposition is presented in the following figure. Are represented: the digital model decomposed into objects, the semantic tree and graphic illustrations of objects of the model.

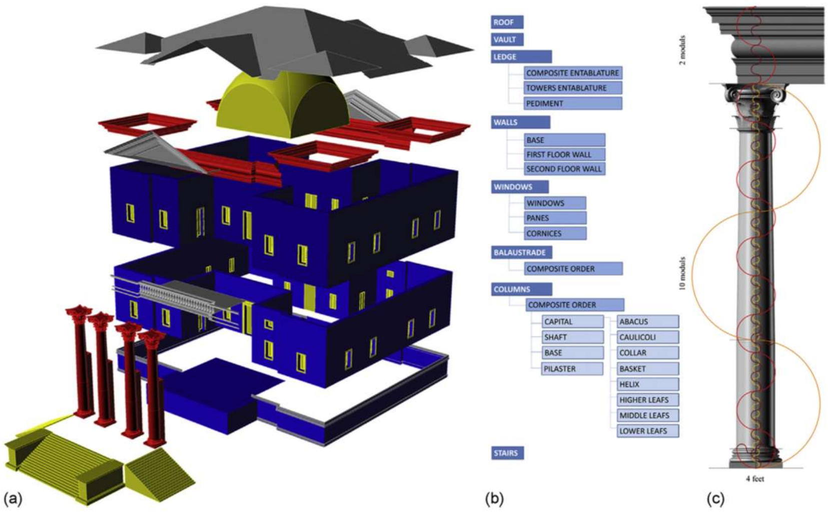

Figure 4. Illustration of semantic decomposition of historical monument objects (Quattrini et al., 205)

Hawas et al. (2017) proposes an approach to creating objects from a cloud of points. The procedure is detailed and illustrated in the following figures.

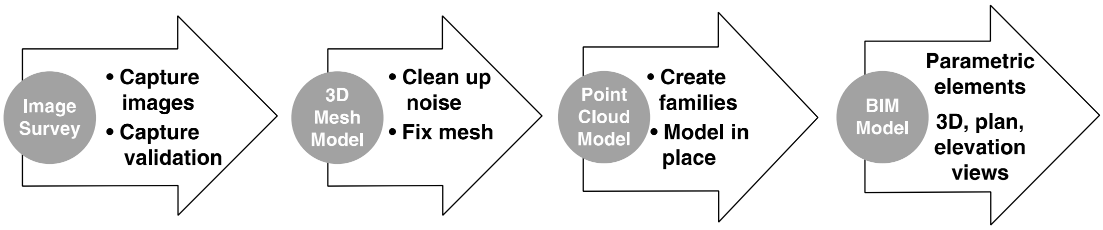

Figure 5. Approach to create an object database based on cloud of points (Hawas et al., 2017)

Figure 6. Illustration of cloud of points (Hawas et al., 2017)

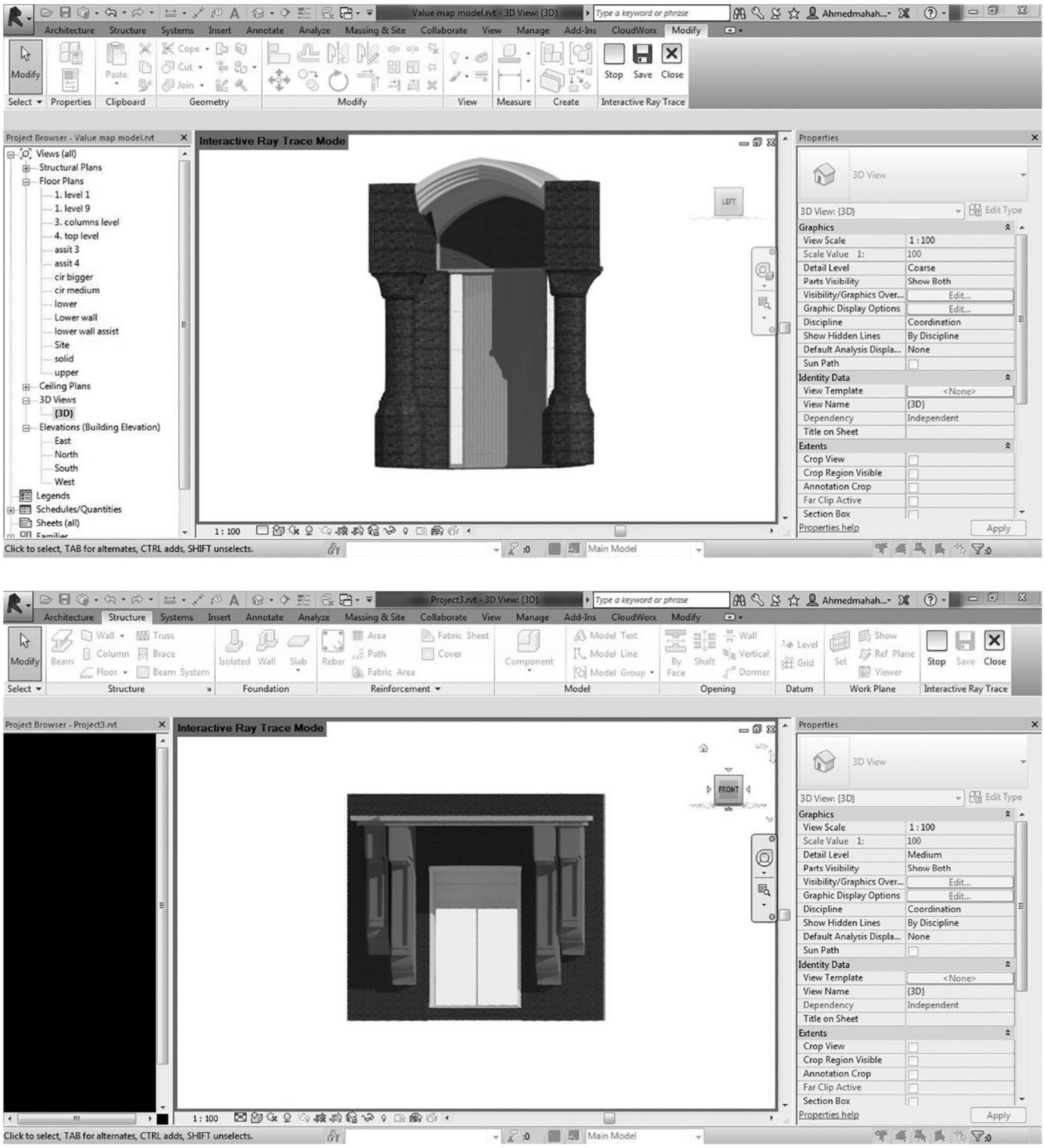

Figure 7. Illustration of objects models with REVIT (Hawas et al., 2017)

Marta Acierno et al. (2016) has developed an ontology for the preservation of historic monuments. The principle of the model developed is detailed in the two following figures.

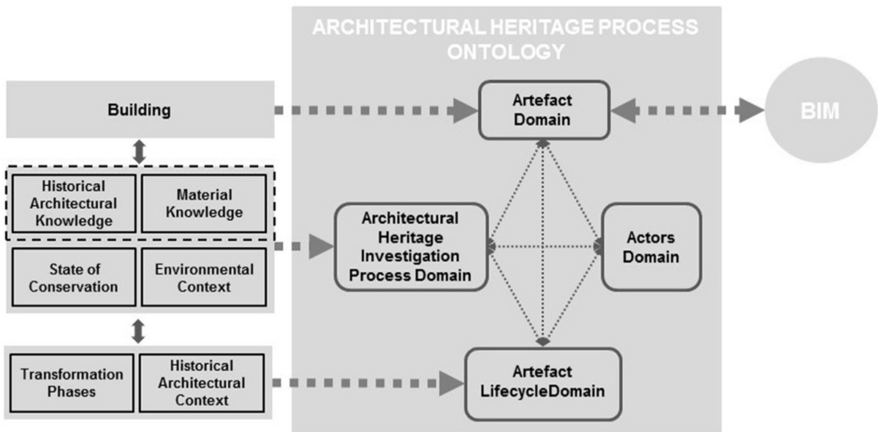

Figure 8. Ontology for the preservation of historic monuments (Acierno et al., 2016)

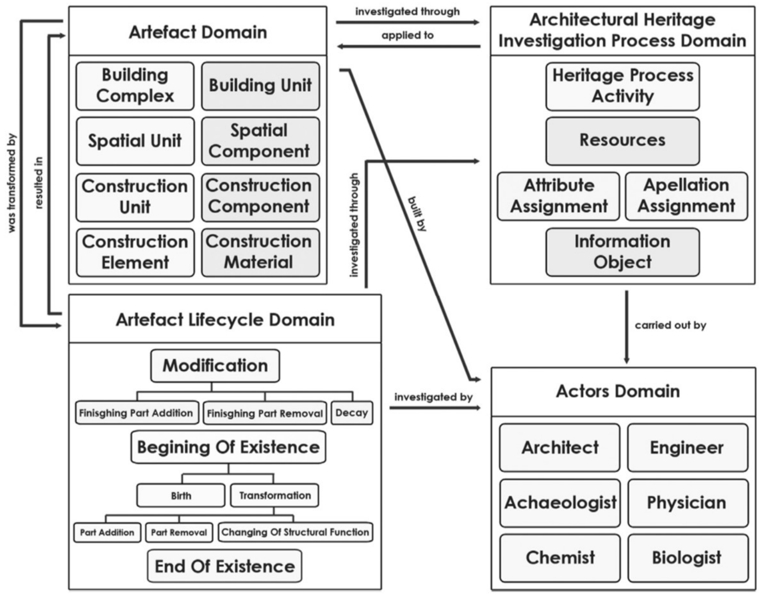

Figure 9. Details of the ontology for the preservation of historic monuments (Acierno et al., 2016)

Regarding the maintenance of historical monuments, Carlo Biagini et al. (2016) has developed cards, using the information contained in a digital model, considering different levels of detail to help the maintenance of monuments historic. An example of a card is presented in the following figure. These plans and sections, made at different levels of detail, can be used to support requests for assistance with financing public works.

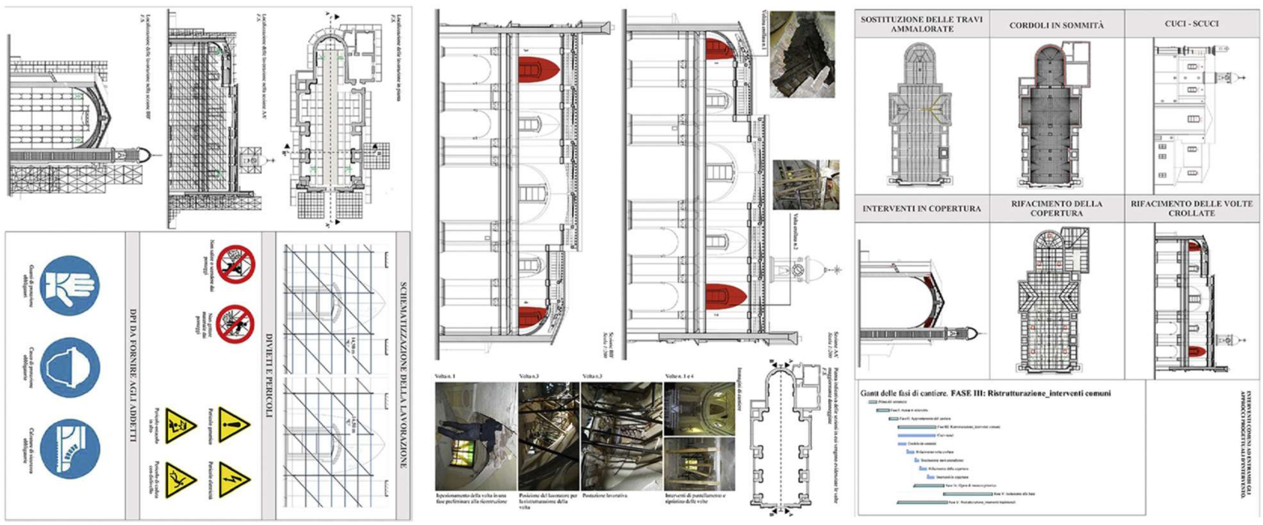

Figure 10. Example of a card of historical monument for helping its maintenance (Biagini et al., 2016)

Laila M. Krodeir (Krodeir et al., 2016) also proposes a BIM-based approach for the preservation of historic monuments.

I.2. State of the art of risk analysis using BIM

HeritageCare project participants are used to applying risk analysis methods to identify the causes of monument degradations, anticipate future degradations and thus define optimal maintenance solutions. The aim of this state of the art is to see if interesting developments have been proposed by the BIM community in this area of risk analysis.

Yang Zou et al. (2015) offers a review of risk analysis methods using BIM. It is synthesized in the following table.

Functionality	Benefits for risk management	Research	Practice
3D visualisation	Facilitating early risk identification and risk communication	Hartmann et al. (2008)	Liu et al. (2014), Shim et al. (2012)
Clash detection	Automation of detecting physical conflicts in model	Hartmann et al. (2008), Tang et al. (2011)	Chiu et al. (2011), Liu et al. (2014)
4D construction scheduling/planning	Facilitating early risk identification and risk communication; improving construction management level	Hardin (2011), Hartmann et al. (2008), Whyte (2002)	Chiu et al. (2011), Liu et al. (2014)
5D cost estimation or cash flow modelling	Planning, controlling and managing budget and cost reasonably	Hardin (2011), Hartmann et al. (2008), Marzouk and Hisham (2014), Whyte (2002)	Motawa and Almarshad (2013)
Construction progress tracking	Improving management level for quality, safety, time, and budget	Bhatla et al. (2012), Eastman et al. (2011)	–
Safety management	Reducing personnel safety hazards	Teizer (2008), Whyte (2002)	–
Space management	Improving the consideration of space distribution and management in design	Hartmann et al. (2008), Kim et al. (2012)	–
Quality control	Improving construction quality	Chen and Luo (2014)	–
Structural analysis	Improving structural safety	Lee et al. (2012b), Sacks and Barak (2008), Shim et al. (2012)	Liu et al. (2014)
Risk scenario planning	Reducing personnel safety hazards	Azhar (2011), Hardin (2011)	Hartmann et al. (2012)
Operation and maintenance (Q&M), facility management (FM)	Improving management level and reducing risks	Becerik-Gerber et al. (2011), Volk et al. (2014)	–
Interoperability	Reducing information loss of data exchange	Ji et al. (2013), Laakso and Kiviniemi (2012)	–
Collaboration and communication facilitation	Facilitating early risk identification and risk communication	Dossick and Neff (2011), Grilo and Jardim-Goncalves (2010), Porwal and Hewage (2013)	–
Urban planning and design	Integrating planning and design of urban space and AEC projects; facilitating land-use planning, design and management	Kim et al. (2011), Lee et al. (2012a), Rajabifard et al. (2012)	Lee et al. (2012a)

Table 4. Review of risk analysis methods using BIM (Zou et al., 2015)

Another use of BIM with regard to risks is to identify the construction phases that may cause accidents. Sijie Zhang (Zhang et al., 2015) defines a set of rules for checking the presence of security elements during different phases of construction. This article looks at analyzing the effectiveness of BIM in this approach by comparing a manually conducted risk analysis with a risk analysis performed using BIM with built-in security verification rules.

The article (Zhang et al., 2013) details the implementation of these security rules in a BIM model. The principle of the developed method is presented in the following figure. Several safety rules are defined, as for example the required height of security fence. The building model is checked as regards this rules. When irregularities are observed, corrective actions are proposed.

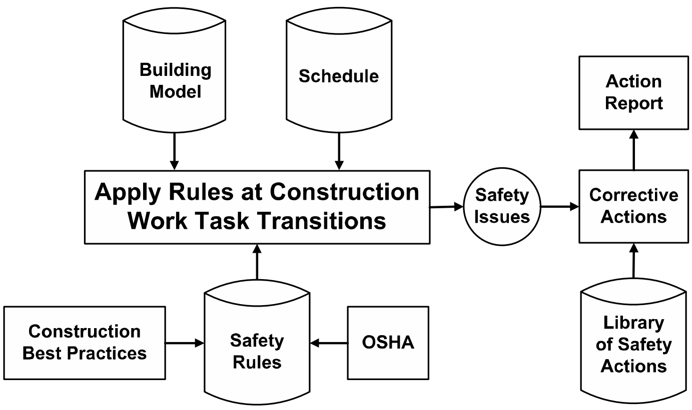

Figure 11. Approach of security rules in a BIM model (Zhang et al., 2013)

Biagnini et al. (2016) indirectly proposes an approach to reduce the risks incurred when carrying out maintenance work. Indeed, it proposes diagrams illustrating the setting up of the elements allowing to realize the works included in the digital model of the historical monument. The following figure illustrates the installation of a scaffold.

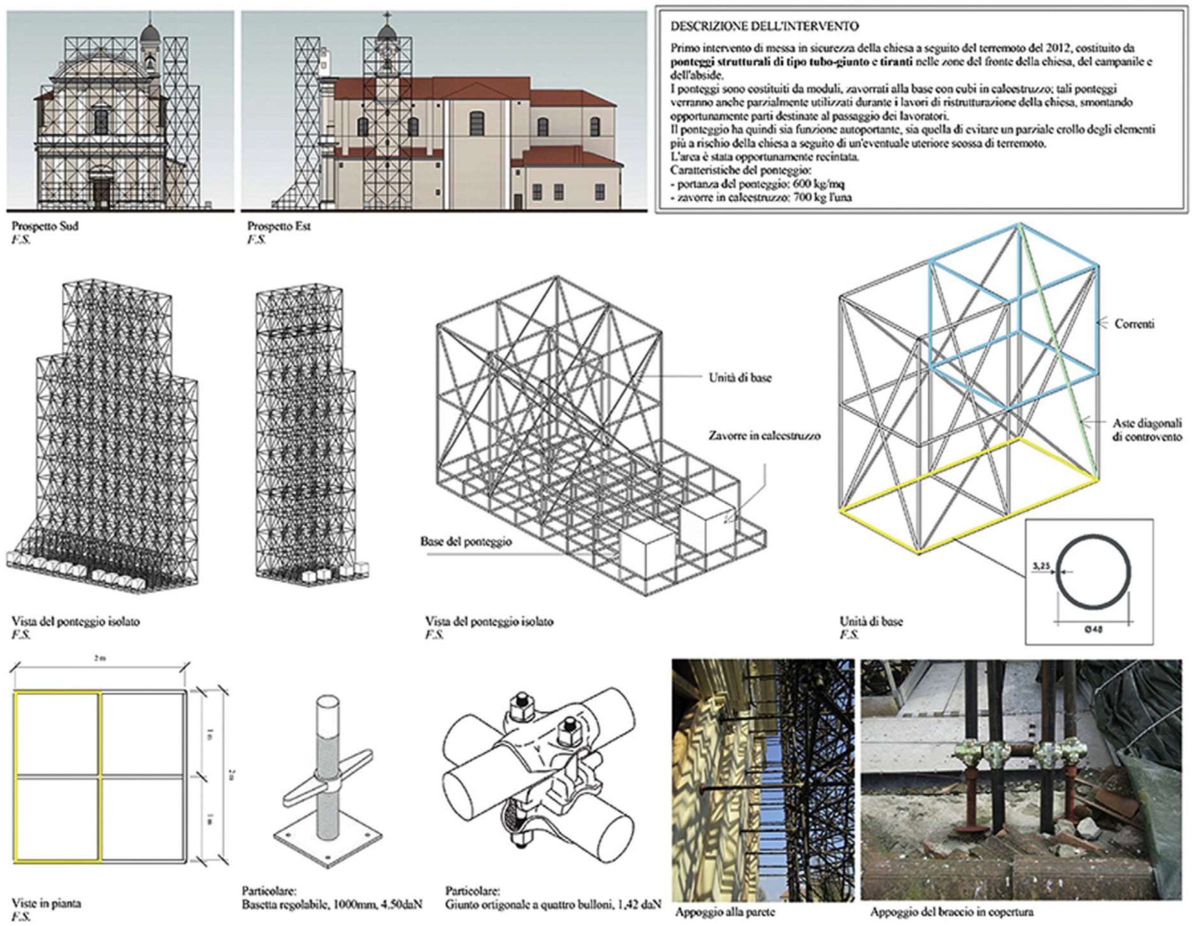

Figure 12. Illustration of the installation of a scaffold (Biagnini et al., 2016)

I.3. State of the art of maintenance methods based on BIM

The numerical model of a building can allow a more appropriate maintenance by a better estimate of the costs, the locations of the defects, the schedules of intervention. The realization of the digital model of the Sydney Opera House after completion of the book testifies to this utility. The following figure shows the possible use of the digital model of the Sydney Opera House.

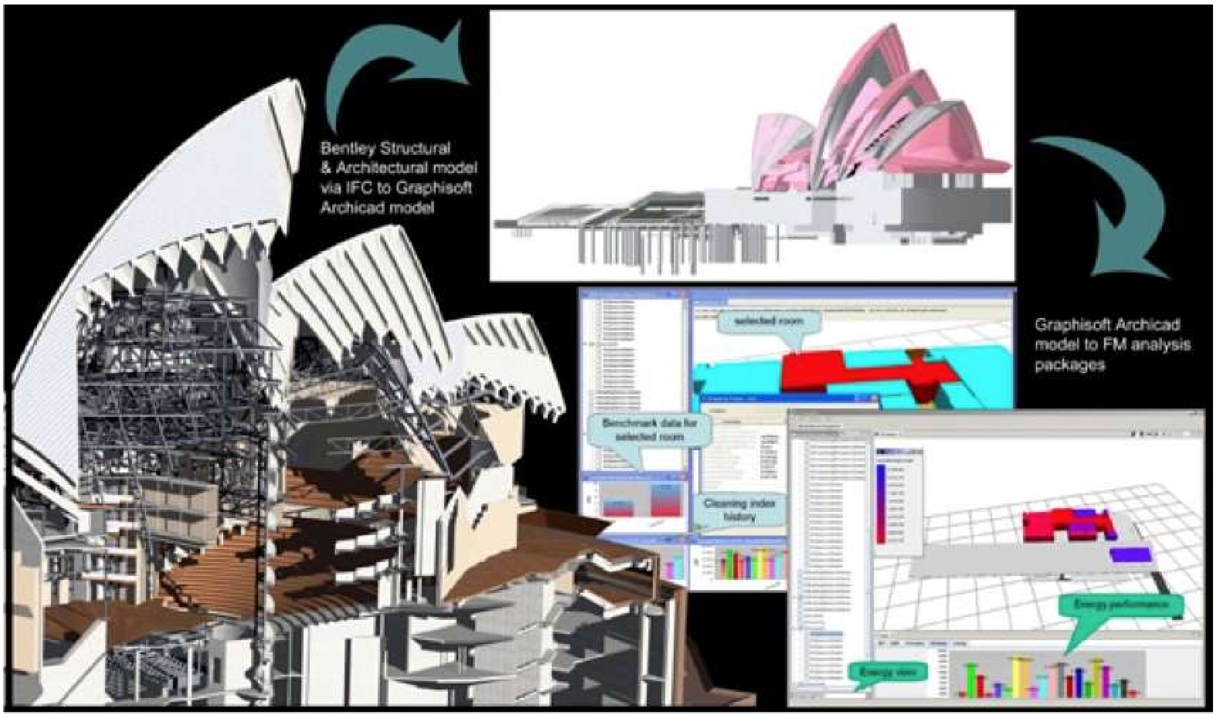

Figure 13. Digital model of the Sydney Opera House and its use for maintenance (Linning, 2018)

Ali Ghaffarian Hoseini et al. (2017) proposes a method of energy analysis of existing buildings based on BIM. In this perspective, proposes a review of all the approaches using BIM allowing the verification of buildings. This review is summarized in the following table.

Aspect	Achievement	Approach	Limitation	Reference
Scanning	Automate the process of as-built 3D laser scanned data	Scan-to-BIM Scan-vs-BIM	Need to be confirmed with more complex scenarios	[8]
Quality Inspection	Dimensional and surface quality assessment of precast concrete elements	3D laser scanning BIM	Limited to the single type of element, single type of scanner, the measurement noise of the sensor	[38]
As-built 3D reconstruction	Automate the process of as-built 3D reconstruction of civil infrastructure	Computer vision-based algorithms	Occlusion, accessibility, visibility, missing data, moving objects, harsh jobsite conditions, camera calibration	[39]
Structural Simulation	Convert a historic BIM into a finite element model for structural simulation	Cloud-to-BIM-to-FEM	Can be used only for modern and regular buildings with predefined object libraries	[40]
Monitoring	Monitor the environmental impacts of construction in VR	Green BIM	The lack of computer tools and the complications of the BIM models	[41]
Building energy visualization system	Visualize the process of low energy building design	BIM-GIS Web-based Visualization System	Limited in user access control and the difference in standards and data description, data format conversion	[42]
Low-carbon building (LCB) measures assessment	Select LCB measures	PROMETHEE Fuzzy LCB measures BIM	N/A	[38]
Facility Management	Improve building management and performance	7D BIM RFID	N/A	[29]
LEED certification	Integrate BIM with LEED system	BIM LEED system	This method is limited in the LEED instead of the general framework of sustainability	[43]

Table 5. Review of methods for the verification of buildings, using BIM (Ghaffarian Hoseini et al., 2017)

In the context of historical monuments, infrared thermography can be used to locate moisture-type defects that can cause damage to stones, for example.

Serge Chardon et al. (2016) also proposes an energy evaluation approach for buildings, but intended for individual homes.

Ibrahim Motawa et al. (2013) suggests associating a knowledge base of maintenance carried out on a set of case studies, so via the BIM, to propose appropriate maintenance approaches when similar pathologies appear on the building course of study. The structuring of the proposed approach is detailed in the following figure.

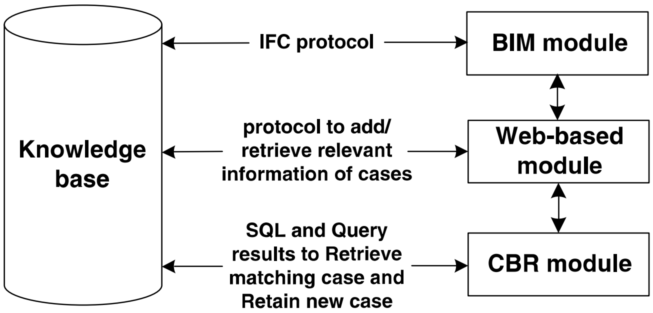

Figure 14. Approach for the detection of pathologies (Motawa et al, 2013)

The principle of the BIM module developed is presented in the following figure.

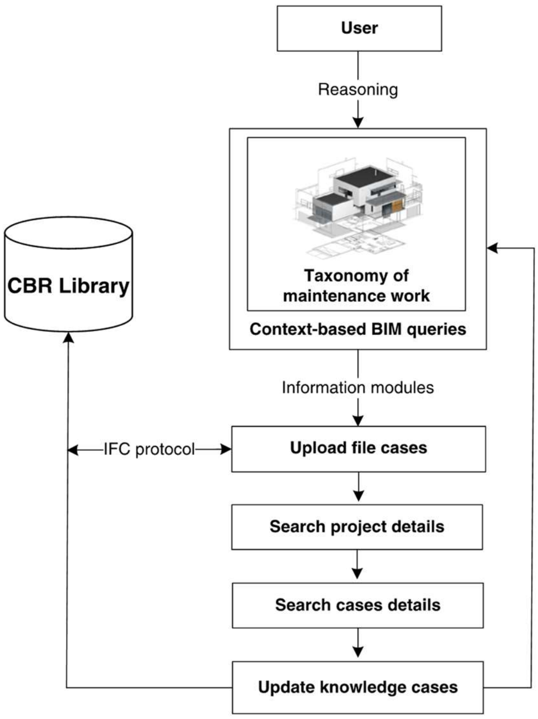

Figure 15. Details of the BIM Module of the figure 14 (Motawa et al, 2013)

In order to be able to locate more precisely the defects on a masonry facing, Valero et al. (2017) have developed an application to identify and represent the precise shape of stone masonry. Valero et al. Review of current practice in the field of surveying and evaluation of historic masonry, with a focus on random rubble masonry and lime works. New technologies in two areas: (1) novel reality capture technologies, in particular TLS and PG; and (2) ICTs for the structuring and management of this data, including (H) BIM. The following figure shows the results that can be obtained.

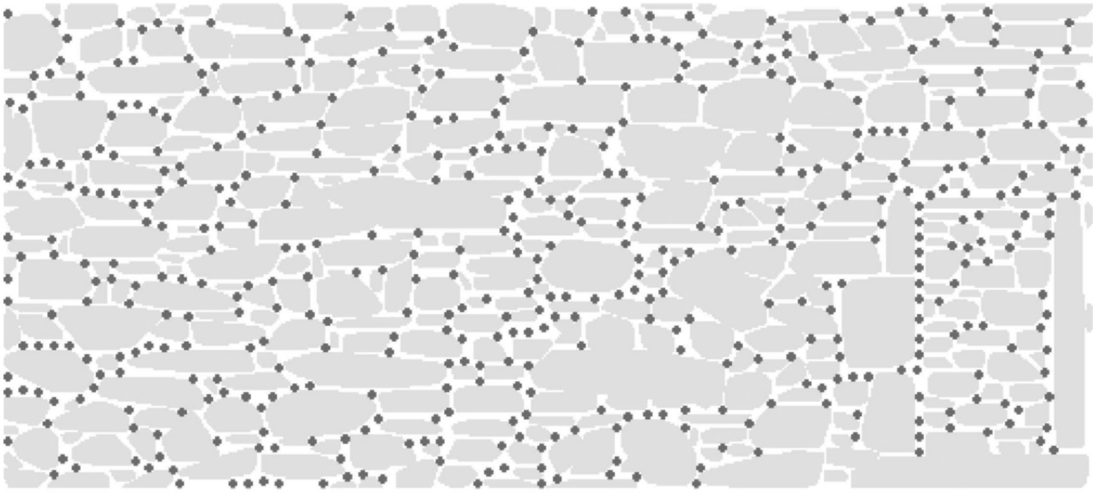

Figure 16. Automatic detection of the shape of stones and joints (Valero et al., 2017)

II. HBIM developed in the context of HeritageCare project

This paragraph is devoted to the presentation of the context and objectives of the project, to the different management levels envisaged as well as to the HBIM principle that will be developed.

II.1. Context and objectives of the HeritageCare project

The HeritageCare project is an Interreg Sudoe project involving Portuguese partners (University of Minho, Regional Directorate of Culture of the North, Computer Graphics Center), Spanish (University of Salamanca, Foundation Santa Maria La Real, Andalusian Institute of Historical Heritage) and French (Clermont Auvergne University and University of Limoges). These national consortia strengthen these institutional partners. The French consortium includes:

- The Pantheon Architecture Workshop (architectural firm),
- Louis Geneste (business of rehabilitation of historical monuments),
- Pascal Parmentier (heritage architect),
- National School of Architecture of Clermont-Ferrand,
- The Auvergne Rhône Alpes region (representatives of the managers),
- The inventory service of Limousin,
- The DRAC.

This project started in July 2016 for a period of three years and aims to make the non-profit entity created under this project sustainable.

The HeritageCare project was born following two observations. The first finding is the lack of an appropriate heritage management system, which includes monitoring, inspection and preventive maintenance. The second finding is the need to develop a system of preventive conservation of historic buildings, including unclassified buildings.

The objective of this project is to set up a non-profit entity to:

- Sensitize owners of buildings of historical and cultural value to carry out inspections and preventive maintenance procedures,
- Develop and apply new and advanced inspection technologies for the diagnosis and management of built heritage preservation,

- Involve society, the scientific and technical community, public institutions and the conservation sector in a more efficient and sustainable way for the protection of historical and cultural heritage.

This project, for the French part, is interested in the movable and immovable heritage of historical monuments classified and inventoried regions of Sudoe space: Auvergne Rhône Alpes, New Aquitaine and Occitanie.

II.2. Levels of management

Three levels of management are envisaged within the framework of this project, which are associated with different diagnostic techniques (visual, destructive and non-destructive auscultation, etc.) and a level of detail and more or less important information. These three levels are shown schematically in the following figure.

As part of this project, it is planned to diagnose 60 historical monuments (20 in each country). Level I diagnosis will be carried out on 20 monuments. Of these twenty monuments, five will be diagnosed at level II and one will be studied at level III (realization of a HBIM).

The first level of management is the completion of a thorough inspection (mainly visual) according to a protocol that will be defined within the project. These inspections will be carried out regularly (with a period of 1 to 3 years). The results of this first level of management will be a report on the state of conservation of the movable and immovable elements of the buildings as well as recommendations regarding urgent or short term interventions.

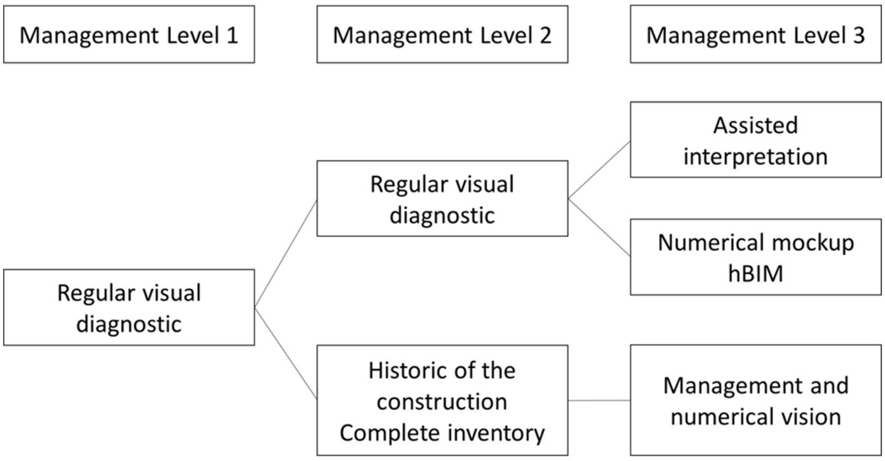

Figure 17. Three levels of management considered as part of the HeritageCare project

The following figure illustrates the inspections as they might be conducted: essentially visual inspections requiring specific equipment to gain closer access to the elements to be observed.

Figure 18. Illustration of diagnostic of management level 1

The second level of management leads to:

- A complete geometric survey of the photogrammetry device (or 3D laser) using robotic units or drones (terrestrial and aerial). This type of result is illustrated in Figure 4: the different steps - measurement and assembly - of a photogrammetry are detailed;
- Information collection and integration of Level I investigations and complete additional inspections (position sensors, technical reports, preventive conservation);
- A classification of the inventory of movable heritage, as illustrated in Figure 3.

Figure 19. Illustration of the asset classification management level 2

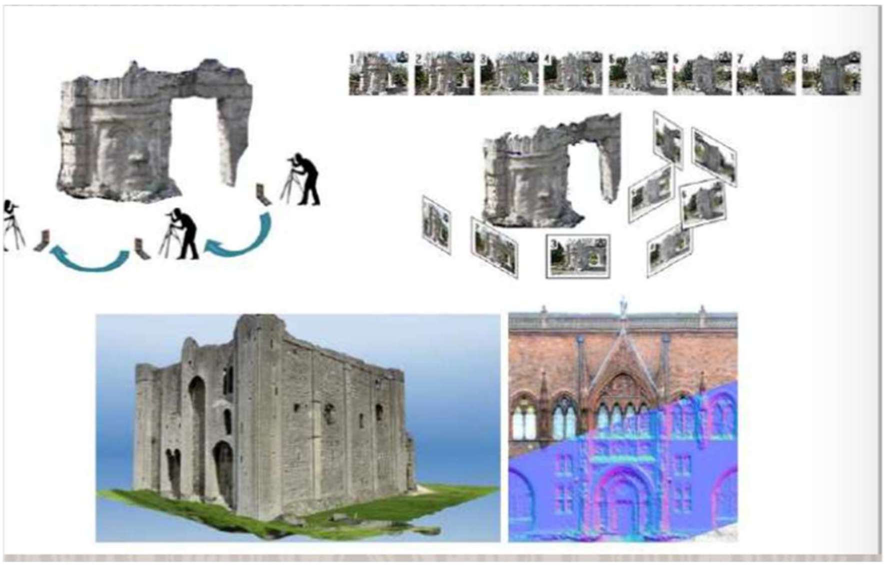

Figure 20. Illustration of the result of a management level geometric survey 2

The third level of management is to use a hBIM model that will include all the information from:

- Geometry,
- Materials,

- Conservation state,
- Integration of information from management levels I and II,
- Structural and non-structural monitoring systems,
- Conservation / maintenance plan: preventive tasks (types and quantities),
- Financial management.

The following figure illustrates the type of result that could be obtained at the end of a level III management level. The developed hBIM will make it possible to locate the different historical monuments on a territory, to propose analyzes (thermal, structural, etc.), to locate the diagnostic results of levels I and II, to represent the phasing of the work to be done, etc.

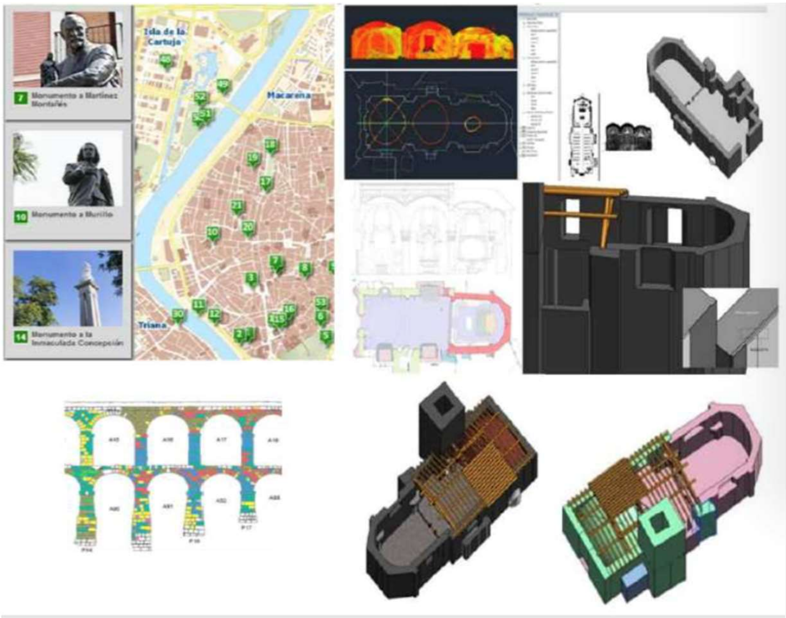

Figure 21. Illustration of a management level 3 hBIM template

II.3. HBIM of the HeritageCare project

As part of the HeritageCare project, the developed hBIM will have three functions:
- Operational monitoring of diagnostics and maintenance work,
- Storage of information,
- A means of communication.

The creation of hBIM digital mockups requires the development of a library of specific objects for historical monuments. The structuring of this object library can be based on the thesaurus of the naming of architectural works and spaces developed on the one hand and on the thesaurus of the naming of movable objects on the other hand. The properties associated with these historical objects will be: their dimensions, their shape, their material, their date of construction, the environmental agents soliciting, the possible actions on the other objects and as far as possible the kinetics of degradation of the phenomena affecting these objects.

Laser 3D analysis and photogrammetry, conducted at the Level II diagnostic level, will provide the point cloud for the development of a digital mock-up and the graphic representation used in the communication for the promotion of this monument.

The digital models of the monuments diagnosed would be the support of the operational follow-up of the diagnoses insofar as they would allow:

- To know the state of the monument through the results of level II diagnoses,
- To know the aging of the monument, that is to say to know the dates of appearance of the phenomena of degradation and thus to foresee the maintenance work to be programmed,
- To help with the programming of the works (via metrics, prices, etc.).

The storage of information consists in grouping together in the form of a database attached to the digital model, all the useful information relating to a monument diagnosed:
- Historical documents on construction,
- Regulatory texts for monitoring and carrying out maintenance work,
- Manual of maintenance and monitoring of the monument,
- Methods of carrying out maintenance work,
- Diagnostic reports made,
- Etc.

The graphic 3D modeling of a historic monument allows to increase the promotion of this monument and to make accessible to the general public inaccessible places since too vulnerable (crypt for example).

Conclusion

This paper develops in a first part the state of the art on the preservation of historical monuments based on the HBIM. HBIM is seen as a way of bringing together all the necessary information (3D representation, history, diagnostics, videos, etc.) to the maintenance. The research developed concerns the techniques used to obtain the 3D models (laser, photogrammetry, scan, radar, object libraries), the diagnostic assistance for the maintenance and the verification of the security for the realization of the works. In a second part, the context, the different levels and the development of HBIM as part of the HeritageCare project are developed. This project is moving towards the creation of a parametric object library, the creation of an information database (diagnosis, history, costs, etc.) related to digital models and the development of a tool help with maintenance planning extracting useful information from digital mockups.

Credits

This research project is funded by the European project HeritageCare and was presented as part of the EduBIM 2017 conference.

Bibliographical references

Acierno, M., Cursi, S., Simeone, D. & Fiorani, D. (2016). Architectural heritage knowledge modelling: An ontology-based framework for conservation process. *Journal of Cultural Heritage*.

Baik, A. (2017). From point cloud to Jeddah Heritage BIM Nasif Historical House – case study. *Digital Applications in Archaeology and Cultural Heritage*.

Bhatla, A., Choe, S.Y., Fierro, O. & Leite, F. (2012). Evaluation of accuracy of as-built 3D modeling from photos taken by handheld digital cameras. *Automation in construction, 28,* 116-127.

Biagini, C., Capone, P., Donato, V. & Facchini, N. (2016). Towards the BIM implementation for historical building restoration sites*. Automation in construction, 71*, 74-86.

Chardon, S., Brangeon, B., Bozonnet, E. & Inard C. (2016). Construction cost and energy performance of single family houses: From integrated design to automated optimization. *Automation in construction, 70*, 1-13.

Choay, F. (1996). *Allégorie du patrimoine*, Ed. Le Moniteur.
Choay, F. (2009). *Patrimoine en questions – Anthologie pour un combat*, Ed. Le Moniteur.
Counsell, J., Smith, S., & Aldrich, S. (2003). A role for 3D modelling in controlling webcams and interpreting real-time video. *In Geometric Modelling and Graphics Proceedings. International Conference.*
De Luca, L. (2009). *La photomodélisation architecturale – Relevé, modélisation et représentation d'édifices à partir de photographies*. Ed. Eyrolles.
GhaffarianHoseinia, A., Zhanga, T., Nwadigoa, O., Ghaffarian Hoseinib, A., Naismitha, N., Tookeya, J. & Raahemifarb, K. (2017). Application of nD BIM Integrated Knowledge-based Building Management System (BIM-IKBMS) for inspecting post-construction energy efficiency. *Renewable and Sustainable Energy Reviews, 72,* 935-949.
Hawas, S. & Marzouk, M. (2017). *Information modeling approach for documenting historic buildings in Egypt. Heritage Building Information Modelling*. Ed. Taylor & Francis.
Khodeir, L.M., Aly, D. & Tarek, S. (2016). Integrating HBIM (Heritage Building Information Modeling) Tools in the Application of Sustainable Retrofitting of Heritage Buildings in Egypt. *Procedia Environmental Sciences, 34,* 258-270.
Linning, C. (2018). *BIM and facilities management at the SOH*. URL : https://jackgraham4.wordpress.com/john-mitchell-bim-and-facilities-mangement/ (2018).
Littlefield, D. (2017). *Heritage and time – Mapping what is not there. Heritage Building Information Modelling*. Ed. Taylor & Francis.
Motawa, I., Almarshad, A. (2013). A Knowledge-base BIM system for building maintenance. *Automation in construction, 29,* 173-182.
Murphy, M., McGovern, E. & Pavia, S. (2013). Historic building information modelling – adding intelligence to laser and image based surveys of European classical architecture. *ISPRS Journal of Photogrammetry and Remote Sensing, 76*, pp.89–102.
Quattrini, R. & Baleani E. (2015). Theoretical background and historical analysis for 3D reconstruction model. Villa Thiene at Cicogna. *Journal of Cultural Heritage, 16,* 119–125.
Rua, H. & Gil, A. (2014). Automation in heritage – Parametric and associative design strategies to model inaccessible monuments: The case-study of eighteenth-century Lisbon Águas Livres Aqueduct. *Digital Applications in Archaeology and Cultural Heritage, 1*, 82-91.
Sabry Hegazi, Y. (2017). *HBIM applications in Egyptian heritage sites. Heritage Building Information Modelling*. Ed. Taylor & Francis.
Thibault, J.P. (2009). *Petit traité des grands sites*, Ed. Le Moniteur.
Valero, E., Bosche, F., Forster, A., Wilson, L. & Leslie A. (2017). *Evaluation of historic masonry – Towards greater objectivity and efficiency. Heritage Building Information Modelling*. Ed. Taylor & Francis.
Zhang, S., Sulankivi, K., Kiviniemi, M., Romo, I., Eastman, C.M. & Teizer, J. (2015). BIM-based fall hazard identification and prevention in construction safety planning. *Safety Science, 72*, 31-45.
Zhang, S., Teizer, J., Jin-Kook Lee, J.K., Eastman, C.M. & Venugopal, M. (2013). Building Information Modeling (BIM) and Safety: Automatic Safety Checking of Construction Models and Schedules. *Automation in construction, 29*, 183-195.
Zou, Y., Kiviniemi, A. & Jones, S.W. (2015). A review of risk management through BIM and BIM-related technologies. *Safety Science*.