Linking HBIM graphical and semantic information through the Getty AAT: Practical application to the Castle of Torrelobatón

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Abstract. The current approaches for the built heritage documentation and modelling are to collecting, organizing and integrating immovable assets’ data into a single graphic-semantic structure using BIM tools. This is the key issue to shifting from point clouds to HBIM. Although fully automation is not possible, practical approaches for the conversion of point clouds into HBIM elements grouped in libraries have recently appeared to meet the particular characteristics of historic buildings in an equivalent way to the libraries of elements already available for contemporary building and civil works. In spite of the graphic information on the built heritage elements is semantically rich in itself, linking the families of modelled elements with the Getty Art & Architecture Thesaurus (AAT) as worldwide well-known controlled vocabulary, allows not only the automation but the consistency in cataloguing of required elements, as well as more efficient retrieval of information in a standardized way. This so useful graphic-semantic linking is particularly applied to the Castle of Torrelobatón to make up the HBIM meaningful set of fundamental elements of the defensive architecture from the Middle Age to the Renaissance in Europe, of which this Castle is a representative example.

1. Introduction
Obtaining structured 3D digital models to document the built heritage is really an urgent necessity. Nowadays, a high level of automation can be achieved through the use of 3D surveying technologies, which allows accelerating the collection and subsequent processing of spatial data at adequate level of detail and accuracy. Point clouds can be incorporated into the Building Information Modelling (BIM) platforms that have the ability to import, manipulate and manage graphic and non-graphic information, as well as historical data [1]. In particular, the 3D virtual objects modelled using architectural historical documentation and 3D surveying data allows to generate a library of elements under the Heritage Building Information Modelling (HBIM) concept.

Today, the conversion of point clouds into HBIM elements grouped in libraries, adapted to the particular characteristics of historic buildings, is a relevant pending issue for the heritage sector [2, 3, 4, 5, 6]. Therefore, thanks to the qualities of HBIM for the management, documentation and reconstruction of the built heritage, a series of relevant publications have been generated during the last years.

A case study on the virtual modelling and reconstruction of a representative Romanesque church just following a straightforward procedure, so practical as easily reproducible to other kind of buildings of cultural interest is offered in [7, 8]. The different components are semi-automatically modelled within Autodesk REVIT commercial BIM software, and used to create a library of parametric elements under the HBIM concept. Another work [9] uses also the REVIT platform to
develop a new approach that facilitates the temporal calculation, order and control of future architectural heritage restoration projects.

Authors such as [10, 11, 12, 13] focus their research on the development of a HBIM library that can help professionals to visualize a representative 3D model, learn the real information of each object and integrate and exchange information between stakeholders.

For their part [1, 14] emphasise the implementation of algorithms that work by selecting the point cloud surface and recognizing the shape, dimensions and characteristics of each element, reducing in this way the time and resources needed to model HBIM libraries of an already constructed building. These approaches would be affordable for any restoration project.

Other representative authors argue that BIM platforms are not currently able to solve all the issues that come from the modelling of architectural heritage, so they integrate other instruments or auxiliary tools. The works [15, 16, 17] propose a simple integration methodology between point clouds and historical data with the REVIT platform and the RHINOCEROS software to generate the HBIM library of the analysed building. These documents present case studies related to Italian Romanesque churches and certain objects were specifically developed for use in other projects with the same architectural style.

Authors such as [18, 19, 20] integrate BIM platforms and geographic information system (GIS) to perform a semantically rich 3D building model. In addition, they emphasize that the elements of the resulting HBIM libraries represent the reality of the monuments and assist other researchers to automatically perform the 3D virtual models of the historic buildings with the same architectural style.

Other works such as [21, 22, 23] are worth mentioning. These documents propose an innovative methodology for processing, cataloguing, analysing and identifying the building's historical and graphic information. In addition, they integrate this information with both Graphisoft ARCHICAD and REVIT software's to simplify the parametric modelling of the architectural heritage. The resulting models will serve as the basis for the creation of an HBIM library that guarantees the interoperability of the information with other interested professionals.

Additionally, an effective HBIM approach needs further semantic enrichment to embed cultural heritage knowledge. Defining an adequate ontology (a formal representation of knowledge as a hierarchy of concepts within the cultural heritage domain), using a shared vocabulary to denote the types, properties and interrelationships of cultural heritage aspects, is obliged.

The Getty AAT is the internationally recognized structured vocabulary responding to the gradual automation of records related to fine art, architecture, decorative arts, archival materials, and material culture [24]. It consists of around 44,000 concepts, including 131,000 generic terms, descriptions, bibliographic citations, and other information.

The Getty AAT is a thesaurus in compliance with ISO and NISO standards including ISO 2788:1986 (Guidelines for the establishment and development of monolingual thesauri); ISO 25964:2011 (Information and documentation-Thesaurus and interoperability with other vocabularies) and ANSI/NISO Z39.19:2010 (Guidelines for the Construction, Format, and Management of Monolingual Controlled Vocabularies). It is made available via the Web browsers to support limited research and cataloguing efforts. Companies and institutions interested in more extensive use are advised to explore the Linked Open Data releases. APIs are available. Relational tables and XML releases are also available, but may be discontinued in the future. All releases are available under the Open Data Commons Attribution License (ODC-By) 1.0.

2. Methodological approach

The practical approach cited in [7, 8] is applied right now to the Castle of Torrelobatón (Gothic castle of the XV century), linking the families of modelled elements with the Getty AAT, whenever possible. The global point cloud gathering internal and external surfaces is obtained and compared to the technical and historical construction details of the different architectural periods. This feedback between the spatial and semantic data allows the complexity of the modeling process required by the HBIM library to be reduced. Once the global point cloud is imported into REVIT, three main steps are applied.

The first step covers the collection of historical data (considered semantic information), as well as the technical documentation (considered graphic or spatial information). It was necessary to carry out a bibliographical study to take into consideration the rules, patterns and architectural proportions of the construction period the building belongs to. The works [25, 26, 27, 28, 29] help to understand and support the modeling of parametric objects that the virtual model will consist of. Another key aspect is the original graphic information collected from the surveying campaign (high-res pictures).
The second step is focused on the accurate and efficient modeling of the different architectural components that make up the HBIM library of the castle according to the Getty AAT, given that point clouds provide the actual deformations caused by the passage of time or structural problems, such as sloping walls, cracks or missing elements. To address this issue multiple cuts, sections, views, grids and reference lines were created on the point cloud. Cuts and sections are made in longitudinal and transverse directions, showing the composition and internal layout of the building, as well as to generate an estimation of the dimensions of the various elements and surfaces. The sections cross the center of the structural or supporting elements (curtain walls, keep, round towers, bartizan, barley, crenel, buttresses, vaults and other parts that represent the constructive logic). This strategy allows the deformations that affect the elements to be reflected more accurately and clearly. The finite horizontal planes constitute a reference for determining vertical distances. Subsequently, a set of grids are created to marking the outline of the cloud surfaces. When the geometry of a given surface is uniform and simple, the modeling is done using the parametric objects available in the REVIT internal library, such as walls, windows, doors or columns (Fig.1A). Moreover, the objects can be readily take part of the BIM project following the grid lines, levels and cloud sections (Fig.1B).

![Figure 1: A) Geometry modeled with the walls of the REVIT internal libraries. B) The wall is modeled on the grid that delimits the point cloud.](image)

Source: Own figures.

In case of the geometry of a surface is irregular or complex, the modeling starts sketching of vertical and horizontal reference planes upon a 2D base plane. Subsequently, the use of reference lines is the key to drawing the profile of any element providing a solution for 3D modeling of a wide range of buildings in the same style. This is possible due to the flexibility of the modelled elements, which can change in form and proportions, thus adapting to new requirements and projects without having to start from scratch.

Finally, the third and last step is just to link the spatial data and the Getty AAT vocabulary to the designed parametric elements. The way to make this association depends on the BIM package in which it is worked on. In the case of REVIT, it is carried out through the option "Type of properties" tool from the menu bar. An example of the semantic organization and parameters of a given object can be seen in Fig. 2A. The properties for every element can be modified by changing the numeric values in the table. Conversely, the Getty AAT vocabulary can be linked to the elements modelled in two ways: (i) by associating the Getty AAT URL with the "Identity data" parameter located within the "Property type" tool (Fig. 2A); (ii) generating a link in the "Properties" palette through the use of "Instance Properties " (i.e. "Information" and "Family"), just associating the Getty AAT URL with the modelled element (Fig. 2B).
The components of the HBIM library are useful not only for cataloguing but for proper performance on the protection, conservation, restoration and dissemination actions for the built heritage. In addition, thanks to the parameters of each component, calculations and simulations on energy efficiency, decay assessment and structural analysis can be made when needed.

3. Results
Out of a total of 18 significant architectural elements (15 with correspondence in the Getty AAT), the most representative graphical-semantic linking is given in Table 1 according to the seven hierarchical architectural levels fixed by the AAT.

The corresponding results are given from Figure 3 to Figure 6, making up the set of fundamental elements of the defensive architecture from the Middle age to the Renaissance in Europe, of which the Castle of Torrelobatón is a representative example. These elements can be verified with the corresponding IFC and RVT files.

| Element [English / Spanish] | AAT ID | Level | Result |
|----------------------------|--------|-------|--------|
| Scarp / Alambor           | http://vocab.getty.edu/aat/300003713 | 3     | Figure 3 |
| Battlements / Almenas     | http://vocab.getty.edu/aat/300002595 | 2     | Figure 3 |
| Bartizan / Garitón        | http://vocab.getty.edu/aat/300003636 | 4     | Figure 4 |
| Machicolation / Matacán   | http://vocab.getty.edu/aat/300002695 | 4     | Figure 4 |
| Corbels / Ménula          | http://vocab.getty.edu/aat/300002695 | 4     | Figure 4 |
| Curtain walls / Muro      | http://vocab.getty.edu/aat/300002504 | 4     | Figure 5 |
| Round tower / Cubo        | http://vocab.getty.edu/aat/300101468 | 3     | Figure 5 |
| Tower keep / Torre del homenaje | http://vocab.getty.edu/aat/300003694 | 2     | Figure 6 |
| Ribbed vault / Bóveda de crucería | http://vocab.getty.edu/aat/300001393 | 6     | Figure 6 |
| Barrel vault / Bóveda de medio punto | http://vocab.getty.edu/aat/30001363 | 6     | Figure 6 |

Table 1: Semantically enriched HBIM library for the Castle of Torrelobatón (Valladolid, Spain)
Figure 3: Highlighted in blue: Left: Scarp; Right: Battlements
Source: Own figures.

Figure 4: Highlighted in blue: Left: Bartizan; Right: Machicolation/Corbels
Source: Own figures.

Figure 5: Highlighted in blue: Left: Curtain Walls; Right: Round towers
Source: Own figures.

Figure 6: Highlighted in blue: Left: Keep; Right: Ribbed vault (up) and Barrel vault (down)
Source: Own figures.
4. Conclusions and Future Work
The multifactorial and multidisciplinary approach required for the research, protection, conservation, restoration and dissemination of the built heritage is increasingly demanding not only innovative BIM interoperable 3D parametric modelling methods keeping complexity and accuracy, but also semantically enriching this graphical information to facing useful HBIM projects. The Getty AAT is a taxonomy based on SKOS, that it is a specification based on RDF (base language of ontologies), formally recognized as standard framework to describe things that are not heritage objects in themselves, but a textual definition of these objects.

Although there is no complete listing for Europe, castles are one of the most widespread type of cultural asset. Thus, a realistic example on the combination of heritage meaningful 3D elements with the Getty AAT taxonomy has been shown for the particular case of the Castle of Torrelobatón (Valladolid, Spain), allowing not only the automation but the consistency in cataloguing of required elements, as well as more efficient retrieval of information in a standardized way as a basis for a trustworthy HBIM ontology.

The Getty vocabularies are compiled resources that grow through contributions from Getty projects and other institutions. Contributors generally represent institutions or consortia such as museums, archives, special collections, visual resource collections, large national or international translation or cataloguing projects, or others who catalogue art. In rare exceptions, a contributor may be an individual scholar.

INCEPTION, as a European representative RTD project, is willing to contribute by defining them to expand that AAT, but it must be done in XML format, according to the Schemas for AAT, TGN, ULAN and CONA. This work will be carried out as next step.

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