Archeologia e Calcolatori
32.2, 2021, 167-176
doi 10.19282/ac.32.2.2021.15

DEVELOPING AN ABIM SYSTEM: A NEW PROSPECTIVE FOR ARCHAEOLOGICAL DATA MANAGEMENT

1. Introduction

The widespread use of 3D topographical data in the research and conservation of archaeological assets has made it essential the set-up of new workflows, which could allow its best application and a successful interface with traditional documentation. High-resolution surveys obtained from laser scanning and photogrammetry are very often employed for the extraction of two-dimensional information (plans, sections, orthophotos, etc.) while most 3D data remain still underused. A large part of the studies in the field of managing heterogeneous data from cultural heritage research has shifted the focus from 3D GIS implementation to the creation of BIM (Building Information Modelling) applications for cultural heritage (Conor, Murphy 2012).

The BIM combines the ability to manage and visualise 3D data with the typical functions of a digital information system standing out because of its scientific accuracy. In the archaeological domain, this approach allows the creation of a complete and accessible data 'container', in which every single aspect of the asset can be immediately available for different purposes (preservation, fruition, maintenance and valorisation); furthermore, a BIM system let the information for future researches available.

BIM was conceived as an integrated system for the design and management of modern civil infrastructures (Eastman *et al.* 2008), but already in the first decade of the 2000s, its potential was tested in the field of the analysis of historical architectural heritage. From multidisciplinary studies the terms HBIM (Historical or Heritage BIM) and then ABIM (Archaeological BIM) were coined. HBIM was designed with the intention of suggesting an advanced methodology to control the processes of management, maintenance and enhancement of historic buildings (Murphy *et al.* 2013). More recently, from the wider HBIM approach a more specific application area was experimented in archaeology; this innovative methodology, named ABIM (Garagnani *et al.* 2016), is focused on the combination of digital survey of the existing archaeological remains with parametric reconstruction of structures, and, above all, on the strong presence of peculiar and often unique elements, distant from the 'traditional' modern structural types. If in the HBIM approach, the building technique and the design can be identified analysing the architectonic elements, in ABIM quite often the architectural components can be supposed only on the basis of the surviving archaeological remains. ABIM supports a more reflexive reconstruction which merges a typical 3D modelling workflow with the checking of different or alternative hypothesis. ABIM project combines 3D graphical data with a description of the archaeological interpretation.

BIM, with its innovative ability to connect aspects of civil engineering with data from analyses of antiquity disciplines, allows a greater transparency of reconstructive hypotheses that are fundamental basis for the research. As far as the use of BIM for historic buildings is concerned, many scholars focused on the way to adapt this approach to the architectural heritage, taking into account that parametric modelling of existing monuments leads to greater complexity (geometric and semantic) in relations to a new design (Potestà 2020).

Since it is indisputable that in the HBIM approach the 3D survey represents an objective starting point for the interpretation of the monument (Centofanti *et al.* 2016), it must be also considered that important information comes from the analysis of the buildings, often in a good state of preservation. Furthermore, fundamental data arise from the knowledge handed down through ancient texts, from the construction techniques, and as well as from the comparison with contemporary buildings.

The HBIM approach cannot be applied in the archaeological field, where often only few centimetres of the structures are preserved, or even only at foundation level. In this context, virtual reconstruction is widely used to hypothesise the likely shape and dimensions of buildings. As the BIM software are based on standard libraries for contemporary building objects, the use of BIM in archaeology requires the creation of specific libraries for the management of ancient architectural elements. This step is not automated and is often quite complex, as it involves the identification of the semantics behind the buildings and its construction techniques (Kreider 2013).

In addition to the geometrical data, ABIM can also contain countless detailed heterogeneous information (photos, drawings, descriptions, annotations) regarding the monument or single parts of it (Bosco *et al.* 2019); from this point of view ABIM is a large archive allowing to link any kind of data, particularly useful for the management of complex architectures or buildings. In this way, an effectively enriched ABIM can be the reference basis for philological, transparent and verifiable reconstructions of any archaeological evidence, as well as a virtual place on which the different professionals, working on the maintenance and valorisation of cultural heritage, can operate. The complexity of the archaeological evidence within a 3D representation must be classified by identifying each individual element that composes it; this process allows the recognition of the structure, function and level of detail to be achieved in the parametric modelling phase. The BIM objects are thus identified and their parameters and the level of information and detail with which they will be coded are established. Categories and types are defined

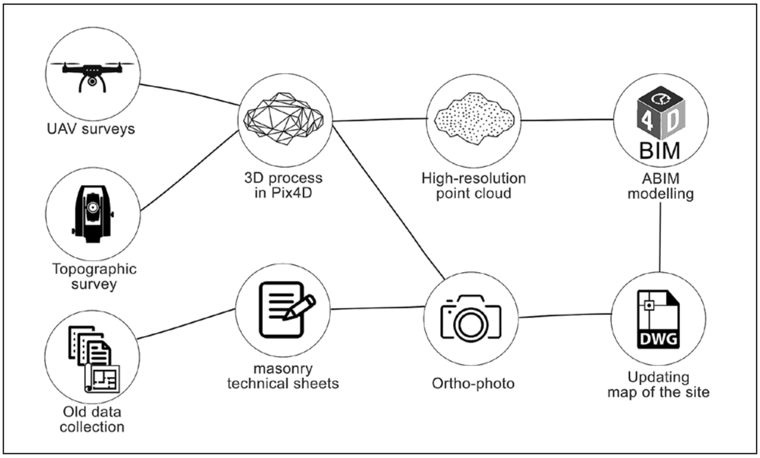

Fig. 1 – Workflow for the reconstructive analysis of *insula* 4-6 of Paestum.

and the chronological phases are assigned. Only at the end of the semantic definition the modelling phase starts. It is therefore essential to correctly define a methodological approach and a precise workflow according to the software chosen for the implementation.

This contribution shows the approach adopted for the reconstruction of the *insula* 4-6 of Paestum. The ABIM contains a digital survey of the existing structures carried out by aerial photogrammetry and an accurate modelling of the still visible walls; the information system has been enriched with the aim to analyse and manage multiple elements of the archaeological buildings (Fig. 1).

2. Paestum: the *insula* 4-6 project

In 2018, a collaboration between the Archaeological Park of Paestum and the University of Naples "L'Orientale" started to re-examine *insula* 4-6 of Paestum. This area has been investigated in the past several times, but despite the numerous on-field investigations, the documentation (photos, drawings, stratigraphic reports) is extremely scarce; the stratigraphical analysis misses completely and the only method to set a date for the archaeological evidences is to study the masonry and the constructive techniques.

The *insula* 4-6 dates back to the Late Republican period with several remakes at the end of Republican age and the beginning of Imperial age. The area has a N/S orientation and it is about 273 m long and 35 m width, corresponding to 120 Roman *actus*. In the northern part there is the large *domus* with a double *atrium* and peristyle and, after a slight variation in altitude, there are the rooms of the *thermae* built on the edge of a large open space, identifiable as the *palestra*. Toward South, there is another house, with the *atrium* and the peristyle clearly visible, while the limits of another possible *domus*, located in the southern strip of the block, appear less precise. This area has never been studied in deep and published, except for minor restoration and maintenance operations (Bosco *et al.* 2019).

The building structures, which characterise the *insula*, are preserved to a minimum height. As these rooms have been frequented for a long time and, therefore, have undergone great changes over time, it is not always clear what was their function in a different phase of life. Therefore, in order to better investigate the chronology, the extension and the organisation of the public and private buildings inside the *insula*, a new approach, based on the creation of a BIM for the archaeological needs, was chosen. Since the modelling process anchors its effectiveness on the true geometric transposition of reality, the survey is of fundamental importance. The so-called 'scans to BIM' process of reverse engineering marks the foundation that supports the entire subsequent parameterisation process.

The characteristics of *insula* 4-6 of Paestum have oriented the choice of surveying the existing structures, by means a photogrammetric acquisition by drone, supported by topographic anchorage to the georeferenced network of the Park. Archaeological research is increasingly using remote sensing methodologies and devices such as UAVs (Unmanned Aerial Vehicles), thanks to the evolution that, in recent years, has made these tools extremely versatile and precise (Remondino 2014). *Insula* 4-6 has an extension of approximately 12,000 m^2 and is located in an area of the Park that is relatively marginal to the visitor route. The almost total absence of obstacles that could hinder the path of the drone allowed a more accurate data acquisition from a low altitude with a consequent increase in the acquired details.

A DJI Phantom 4 was used for the shooting, while the alignments and dataset overlays were done with Pix4Dmapper software. Thanks to the targets arranged in the acquisition area and captured with the aid of the total station, it was possible to rotate the project on the coordinates of the network used by the Park (Bosco *et al.* 2020). The entire process generated a coloured point cloud of 3,897,284 million points. Several layers of information were extracted from the 3D survey, including a high-resolution orthophoto that allowed to quickly update the CAD plan provided by the Park.

3. The ABIM development

The coloured point cloud generated by the aerial photogrammetric survey and the 2D planimetry provided by the Park represent the geometric bases on which the ABIM model was created. After the necessary conversion

Fig. 2 – A partial 3D view of the point cloud in BIM.

of extensions for its correct reading, the point cloud was loaded into the BIM software[1] providing a 3D reference for the modelling of the parametric objects (Fig. 2).

The same cloud was the basis for the creation of the topographical reference surface, indispensable for the correct positioning of the model. To this purpose, the cloud was simplified[2], saved in .txt format and then loaded into the BIM project. Thanks to the geometric and environmental information provided by this data, it was possible to set up the 'reference levels'; the level has guided the construction of the ABIM allowing the design of specific plan and section views. To define semantic relations, the 'wall' object was chosen as a basic unit on which to build the hierarchy of the different architectural elements; the wall defines the semantics of the built environment as well as the LOD (Level of Detail) of the archaeological analysis.

Same families elements were modelled, based on the point cloud, by modifying the system families in the software on the basis of ancient technical construction knowledge (e.g. definition of the stratification of the specific construction technique and materials associated with it) (Fig. 3); for other

[1] Autodesk's BIM software Revit Architecture.

[2] In the open source software Cloud Compare.

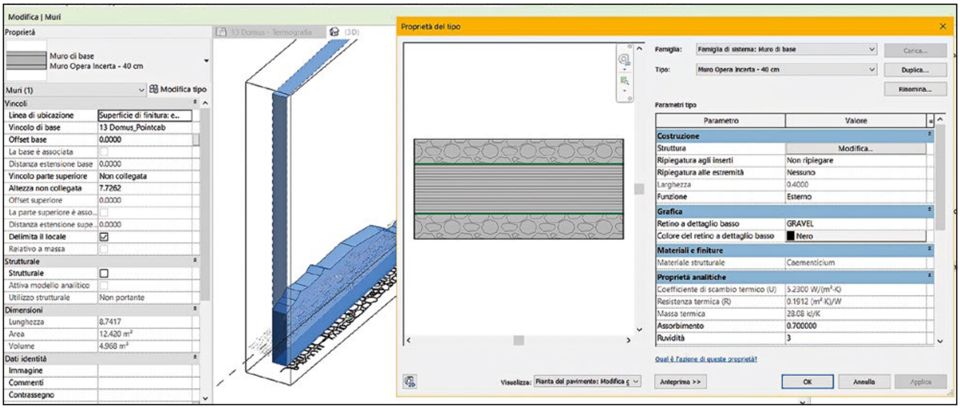

Fig. 3 – An example of a modified system family based on ancient construction techniques.

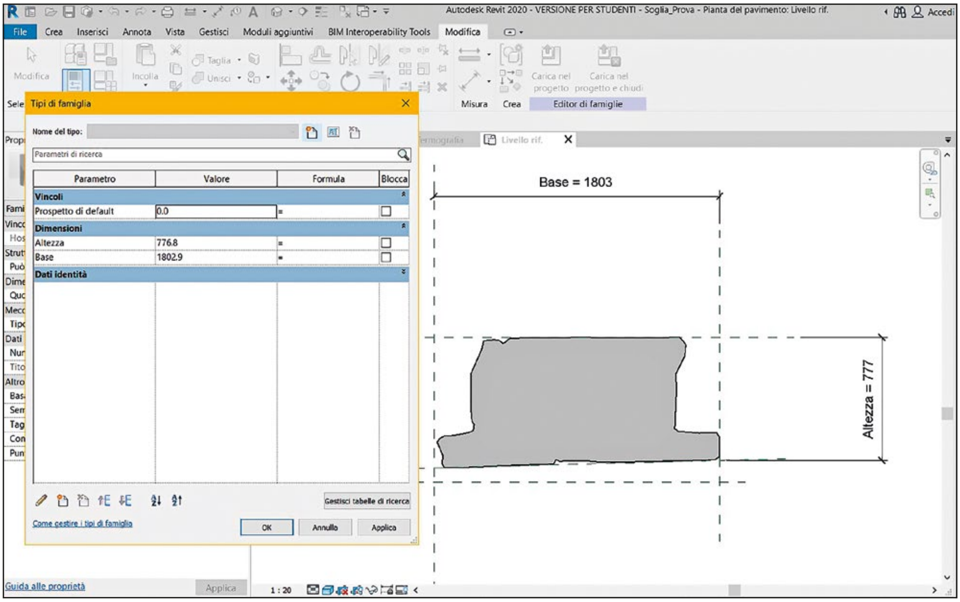

Fig. 4 – Creation in the 'local family' environment of the parametric object 'threshold'.

objects a new family was identified starting from a category of pertinence (e.g. structural, hydraulic, decorative, etc.) and the objects were parameterised, as local models, by defining their dimensions and their variation on the basis of specific measurements obtained from the study of local techniques (Fig. 4).

The specific characteristics of the objects, such as restoration interventions (ancient or modern), phases, state of preservation, etc. were added thanks to the associated information structure. For example, the chronology is annotated in a field dedicated to temporal references; this value can easily express the chronological period of the construction of the entity and its defunctionalisation. The single stratigraphic units, the analysis of degradation or the reconstruction of decorative systems are, instead, defined and noted in special 'views' linked to the specific object and, therefore, easily recalled for inspections and updates. The Properties tab of each object in the model can also be enriched with information through external links. In this way, it is possible to attach photos, archival material such as drawings, texts, and databases of different nature, including detailed 3D surveys, to the single entity.

4. Results

In the framework of the *insula* 4-6 Project in Paestum, a methodological workflow for the creation of an ABIM for data management aimed at the study, use and maintenance of the site, has been developed. Starting from the acquisition of 3D data by drone, the parametric modelling workflow was defined through several phases:

– pre-modelling, which has involved the definition and cataloguing of archaeological objects, construction techniques and specific materials;
– modelling, which has included the creation of archaeological parametric families, whose geometric accuracy was constantly verified through the point cloud provided by the 3D surveys;
– the informative enrichment of the model, which defines numerous aspects comprising the state of conservation and the type of construction; these documents were attached as external reports (e.g., photogrammetry, wall stratigraphy and degradation sheets).

An important aspect focused during the elaboration phases was the identification of the LODs (Levels of Development or Levels of Detail, based on American or Italian legislation), which establish the degrees of accuracy in the virtual rendering of the object in BIM. On the basis of the studies carried out, the concept of LODs has to be completely redesigned for the archaeological needs. In the archaeological field the level of detail of an ancient object is linked to its chronological phase and to its state of preservation, unlikely classifiable as real levels of detail in modelling. The evaluation of the Reliability Level, which takes into account both the geometric conformity and the ontological accuracy of the model with reference to the described reality, has been considered as a valid solution (Maiezza 2019). There is a need for an evaluation system of archaeological objects and models in the BIM environment, LOD for archaeology, which takes into account the specificity of objects whose specific function is closely linked to the chronological context of reference.

For the ABIM of *insula* 4-6, it was decided to enhance the information aspect of the BIM system and to identify increasing degrees of detail in the rendering of BIM objects based on the information related to them. In the 'architecture' section of the software, new 'families' were set up, associated with system types. The creation of libraries of archaeological objects allows to deepen the knowledge of the individual parts of the structure, to organise and plan the documentation to be produced and to attach it directly to the individual parametric element. In addition, ABIM, by bringing together all the geometric and information levels in a single virtual environment, has made it possible for the various specialists involved in the management and valorisation of the asset to access the data, simplifying interrogation and avoiding the loss of data.

5. Conclusions

The archaeological excavations carried out over the years in *insula* 4-6 of Paestum have left a scarce and inaccurate documentation. This has caused the loss of stratigraphic information and structural relationships. Only a detailed analysis of the masonry makes it possible to identify the relationships between the buildings, so as to provide a reconstruction of the life of the *insula* and its changes over time. By means of BIM, the research aims at unifying in a single system the possibility of operating reconstructive hypotheses on the real masonry, guaranteeing its structural reliability and allowing the management of heterogeneous data typical of archaeological research.

The paper, through the case study of Paestum, highlighted how it is possible to apply a BIM approach to an archaeological context, starting from the creation of specific families related to the well-known building typologies of the Roman and Late Antique periods. The creation of standard libraries based on the existing architectural and masonry elements makes the modelling phases particularly complex as the geometrical characteristics are linked to verifiable and reliable measurements and parameters. Furthermore, these libraries can be easily exported in interoperable format and reused for other archaeological sites.

The great versatility of the software's database interfaces makes it possible to customise the records by allowing the inclusion of standard entries for archaeological documentation. This parametric system thus becomes an interactive and interoperable container of archaeological objects, 3D geometric and environmental information, more powerful than a 3D GIS application. The choice was made to optimise the modelling of structures at an intermediate LOD, leaving the more detailed documentation to the annotative functions of the single instance and allowing the linking of multiple data extensions.

Future research perspectives will include the creation of guidelines for BIM application in archaeology; the challenge will be the implementation of open standard libraries covering different sectors of the archaeological domain. This approach will encourage the reuse of data in a multidisciplinary framework and will facilitate the overcoming of the limitation of GIS in 3D management.

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ABSTRACT

In the framework of a collaboration between the Archaeological Park of Paestum and the University of Naples “L’Orientale”, in 2018 the study of the *insula* 4-6 of Paestum has been resumed. The paper shows the so-called ABIM (Archaeological Building Information Modelling) methodological approach that involves combining digital survey with parametric reconstruction of the structures. The study aims to provide a complete information system useful for different purposes, from documentation to interpretation and management of archaeological data, with a special focus on standards and interoperability. For this purpose, CISA (Centro Interdipartimentale di Servizi di Archeologia de “L’Orientale”) carried out an aerial digital survey to provide a detailed and updated map of all the structures still visible, while the point cloud was used to develop the archaeological BIM.