A Pedagogical Approach Using Digitalization and Heritage Building Information Modelling (HBIM) for a New Practice in Architecture and Archaeology

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Abstract: In the past years, architectural heritage was represented and described through 2D plans, sections, perspective drawings, pictures, and texts. But, in the last decades, with the development of digital tools such as 3D scanner laser and photogrammetry, new technologies have been introduced in the digital survey of architectural heritage and 3D modelling. In this regard, we noticed that students, architects, and archaeologists still do not use photogrammetry and lasergrammetry in their work. Some of them found those methods difficult and expensive. This paper aims to describe a methodology of digitizing architectural artefacts based on digital tools such as photogrammetry and lasergrammetry that allows representing realistic and accurate 3D models and then to explain the steps that lead to introducing photogrammetric model from Autodesk recap photo software in the Autodesk Revit software to have a Heritage Building Information Modeling (HBIM) project that is useful for architectural intervention on cultural heritage using digital platform allowing multidisciplinary collaboration in architectural projects. The field of experimentation is our teaching courses with the students at the national school of architecture and urban planning in Tunisia in different sites. The student’s results are promising in the new practice of Digital Architecture and Digital Archeology and the HBIM can be a conception aid design.

Keywords: Digital Heritage, Photogrammetry, Lasergrammetry, 3D Modelling, Google Earth, HBIM

1. Introduction

During the 2020-2021 academic year, a seminar was led for the students in the fifth year. The seminar aimed to train students in photogrammetry, introduce them to the notions of lasergrammetry and lead them to use digital tools for their graduation project, specifically in the analysis of the site, also using the information extracted from satellite images such as Google Earth.

The students were invited to develop photo models of different buildings and then introduced to the BIM Revit software. This allowed to introduce new practices in learning the architect profession.

Subsequently, during the same academic year, a master’s degree research in architecture was led, which allowed to update the literature review concerning modelling practices in photogrammetry and lasergrammetry [1, 2],¹ and draw a summary of the new digital modelling’s practices such as BIM and HBIM [3]. The purpose of the paper is to introduce to the students a new practice in Architecture and Archeology using digital tools. The results show different method of representation of digital heritage and can be helpful in the

design project in Architecture using HBIM.

How to introduce a pedagogical approach using digitalization and HBIM in learning the architect and the archeologist profession, which create new disciplines such as Digital Architecture and Digital Archeology?

2. Literature Review

The evolution of the different techniques of acquiring metric data on the ground provides different instruments which allow the implementation of different approaches and survey modalities.

As a result, the metric topo survey, photogrammetric acquisition, and acquisition by the 3D laser scanner can be used. Each survey method uses its instruments and techniques. We can also benefit from the complementarity between the different methods [4].

Beyond the operating mode, a survey is always selective because a prior choice determines what must be surveyed and in what form (scale, resolution, etc.).

The topo metric survey uses instruments that first determine the horizontality and verticality of the reference plane. The first step is to determine the archaeological problem and the desired degree of precision during the data acquisition phase. The measurement of angles and distances is done using different methods.

There are different methods of topographic survey, what is interesting is to present those which are for archaeological purposes.

“Survey methods derive from the application of a given instrument allowing the definition of the point in space.” [5].

2.1. Use of Photography

The photographs form an essential documentation for the researcher. Taken at different stages, the photos testify at a given moment to an archaeological state which will no longer be observable later and constitutes, in fact, a precious memory.

The photograph can serve as the direct basis for the drawing. It provides "global and dense" information on the object to be surveyed. It makes it possible to develop a description of the various constituent elements, formally and functionally, in relation to the materials used. When dimensions are associated with it, it is possible to size the object to be studied and analyze the ratio of proportions.

Orthophotography has developed considerably for the establishment of cartographic documents. The orthophotography taken from the facade of a building in plan constitutes a background on which architectural representations can be elaborated.

2.2. Digitizing Architectural Artefacts Using Photogrammetry

“Photogrammetry is the science or technique of obtaining reliable information about natural space or physical objects by recording, measuring, and interpreting photographic images…” [6]. (American Society of Photogrammetry, 1980).

The photogrammetric acquisition also uses the postulate of the visual radius. Still, unlike topometric acquisition, it is used in intersection with the perspective plane and defines the position of the elements that make up the scene on two-dimensional support. Photography introduces perspective and, with photogrammetry techniques, allows the reconstruction of the 3D scene and, therefore, the 3D modelling of objects [Figure 1].
As part of the hologram project which is a cooperation project between Italy and Tunisia, a GIS was developed by integrating photo modeling into the platform in TLM format with text and maps. This allowed a structuring of the archaeological data. [Figure 2].

![Figure 2. Web mapping and photo modelling (Meriem Zammel in the Hologram Project).](image-url)
2.3. Digitizing Architectural Artefacts Using a 3D Laser Scanner

Terrestrial laser scanning is based on a ground-based device, which uses a laser to automatically measure the three-dimensional coordinates of a given location on the surface of an object automatically, in a systematic order and at high speed [7].

The acquisition of data by laser scanning allows the recording of thousands of thousands of coordinates of points per second.

“Beyond the spatial coordinates (x,y,z), certain scanning devices thus make it possible to acquire the intensity values (Value expressing the response of the material to the laser beam in a shade of 255 grey levels) and the colorimetric

Figure 3. Scanning and Photo modeling the old charity in Marseille (Meriem Zammel).
values (value expressing the response of the material to the laser beam in a shade of 255 grey levels) and colorimetric values (RGB value extracted from a calibrated camera embedded in the scanning module).” [8].

The panoply of objects that a building can present ranges from architectural elements to sculpted decorations. Therefore, it is necessary to understand these tools’ operating principles to better understand their adequacy with the object to be surveyed. [Figure 3].

The review of these different data acquisition techniques aimed, on the one hand, to synthesise the different existing techniques and present their evolution over time.

After the field data acquisition phase comes the two-dimensional and three-dimensional data processing phases.

3. Data Processing

Digital surveys and models allow the description, analysis and intervention of architectural heritage can only take place by means of a large and very heterogeneous number of documentary sources (texts, images, voice recordings, photos, videos, etc.) and analytical data (from sample analyses, maps from scientific imagery, recorded by 3D laser scanning scanner and multi-view photogrammetry, aerial shots via drones, from geometric modelling, enrichment of models, etc…) [9].

Figure 4. Digital Survey and restitution of the ancient theater of Oudhna in Tunisia (Meriem Zammel).
These resources also make it possible to provide the historical, archaeological, and constructive information necessary to understand the structure and temporal evolution of the heritage structure studied [10]. The heterogeneous nature of these data, since they are produced within the framework of scientific practices and various business processes, reflects the complexity of this knowledge formalisation process, intending to create new information, even new knowledge [Figure 4].

The diversity of experts and stakeholders during the intervention on architectural heritage requires a coherent and systemic modelling of knowledge in databases at each process level with links within a joint representation support, which will be discussed later during the numerical modelling and its tools. During the management of the built heritage, there are generally specifications with requirements depending on the country that will have to be respected. These imperatives are linked to the building in question for which the acquisition techniques mobilised for a survey depend on a large number of technical or contextual constraints, and this is to meet either the imperatives expressed in the specifications or the imperative needs of perception, knowledge and understanding of the preliminary inventory of the works on which the participants in the heritage architectural project whose designers will intervene. The survey of heritage works and the production flow of 3D models generated, whether they come from digitisation or modelling and are generally the result of a complex process that can rely on different hardware or software media. The 3D digital survey and restitution modes have undergone a recent evolution of techniques related to the contribution of digital technology. This has made it possible to provide heritage stakeholders with diverse representations that often hide many questions about the inventory. Considering the two most used techniques, namely photogrammetry and lasergrammetry, it is necessary to judge the capacity of these technologies regarding the restitution of the measurement and the virtual representation of the existing [11].

Moreover, there is yet another means, that of the survey of the general topography of the site also carried out with an electronic tacheometer to be able to reposition the surveys carried out on the site and define the coordinates of the support points intended for the orientation of the photogrammetric models. Historically, the theoretical bases of surveying techniques have been laid since the 15th century. Regarding these three-dimensional surveying techniques, photogrammetry is a technique that makes it possible to acquire reliable data of existing objects by recreating 3D models from photos. The photograph provides dimensional information concerning the object's morphology while constituting sources of textures for the realistic treatment of the model's final appearance. It thus takes a special place during the process [12]. 2D and 3D data are extracted from images acquired by a scanner then, using superimposed photos of the object, these superimposed images are converted into a 3D digital model. This makes it possible to capture large objects, even landscapes, that would otherwise be impossible to scan. On the expert level, surveyors, architects, engineers, and contractors often use photogrammetry to create topographic maps, networks or point clouds. Photogrammetry allows the measurement of an object by the study of its reproduction in perspective, generally using photographs or digital images, even if it is considered an old technique, it remains effective in certain applications, particularly in the production of digital orthophotos [11]. Photogrammetry is a rigorous technique since all the points captured by the method have a mathematical definition. This technique has been used for almost half a century in the most diverse fields, including archaeology, especially for the study of buildings, but also for the survey of heritage works.

Figure 5 3D modeling from photogrammetry and lasergrammetry (source Edificus).

Figure 6 Extraction of facades and representation of pathologies from an HBIM model (source Edificus).
Many of photogrammetry's difficulties must be considered when formalising its data. Indeed, given that it calls upon specific technical skills, firstly at the level of shooting but also for non-automated restitution processing [Figures 5, 6], the method is not applicable and cannot be implemented. Work in all sites (recoil constraints, space, humidity, lighting in a cavity), although certain physical requirements are reduced with digital technology. The three-dimensional survey's second technique is lasergrammetry or laser sensor survey. It is the appropriate acquisition technique to produce a digital terrain model in the different areas of land surveys [Figure 7]. It is characterised in its survey mode by a homogeneous although relative precision.

Lasergrammetry uses motorised digital sensors, or scanners, which will make it possible to identify points in coordinates. Orthophotographs or orthoimages are aerial or satellite images of the Earth's surface that are geometrically rectified and radiometrically equalized. These images in the form of tiles covering an area of the Earth can be georeferenced in any coordinate system. They serve as cartographic backgrounds in Geographic Information Systems. The “Geoportail” and Google Maps platforms or the Google Earth and World Wind software are good examples of tools using orthophotographs to record certain radiometric information [11].

The data obtained by laser scanners is called point clouds, three-dimensional sets of points measured by the sensor on the surface of the object being scanned. These sets at the level of a complete survey provide a large volume of data, which varies according to the measurements' density and the object's nature. Indeed, the main characteristics of 3D point clouds obtained using laser scanners are their extremely large volume, up to several million points, and an inhomogeneous density due to the multiplication of viewpoints and the variable resolution of the scans made depending on the levels of detail required by the complexity of the objects measured. A complete data processing process must be implemented to obtain usable data [12]. To be technically exhaustive, reference can be made to Alain Fuchs' thesis [12], in which the author showed that 3D acquisition devices present an extremely wide range of three-dimensional capture possibilities depending on the nature of the architectural object to be raised. A classification of measuring equipment according to whether they emit energy to measure the scene or not was exposed where the magnetic resonance imaging technique was mentioned. It should be noted that the author has insisted on the interest in the distinction between photogrammetry-type devices and those of the laser scanning type, a differentiation linked to the possibilities of the measuring device. The three-dimensional acquisition chain and point cloud processing software as well as the export of data into computer-aided design (CAD) and computer-aided drawing and design (CAD and CAD) software for creating a 3D model or a 3D digital model [Figure 8].

4. Methodology

With modelling, data flow, digital acquisition techniques including lasergrammetry and photogrammetry, and above all, the BIM and HBIM remote collaborative platforms, the intervention in the architectural heritage is lively from a purely professional expert point of view to undergo radical transformations to be considered in our approach [13]. HBIM experience and heritage-oriented computational design Digital tools, a radiant mark of this millennium, impose themselves as a vector and support for interpretations and representations and as an alternative or complementary investigation methodologies to experimental and theoretical impact profoundly contemporary architectural creation [Figure 8]. “If history has anything to teach us – the digital history of the last 20 years, as much as the architectural history of the last 20 centuries – it is that at best, or at least, the most important days of the digital revolution are still ahead of us.” [14]. Current research in digital architecture, among others, those carried out in built heritage, is mainly centered on the development of tools and not on understanding the phenomena of adoption.
and the apprehensions formulated. However, the understanding of perceptions and phenomena influencing the acceptability and integration of technologies is the subject of little attention. However, the coexistence of the two scientific aims is essential if we want to avoid the development of technologies that are too far removed from the needs of the field, inappropriate and therefore not very sustainable [15]. Let’s consider the existing digital collaborative platforms: BIM and HBIM. These tools have limitations and are considered not very agile and unsuitable for ideation and design [16, 17]. HBIM for Heritage Building Information Modeling was first used by Maurice Murphy [18] (Murphy, 2012). This term indicates a new way of modelling all existing buildings using a BIM process. It requires the generation of intelligent models that can contain and manage information. Models relate to all project components and include their geometric and identifying information and all physical properties that describe them in detail. Historically, the first attempts to return a BIM model of an existing building were linked to historical heritage buildings. The goal was to create a database in which it is possible to insert the models created to disseminate information for various purposes.

**Figure 9. Methodology from the process (Meriem Zammel).**

### 5. Results and Discussion

In these collaborative platforms Figure 9, it is possible to have an environment dedicated to HBIM modelling with the creation of the digital model from point clouds, DXF and DWG drawings, IFC files and modelling of different architectural components. It is also about the possibility of linking orthophotographs to building elements, identifying, and drawing the pathologies of heritage buildings, such as cracks and degraded surfaces. Figures 10, 11.

We obtained the following results from the work of 5th-year students during the Architecture and Technology seminar:

- Point clouds can be introduced into the Autodesk AutoCAD software in DXF. The photo models can be introduced into the 3D studio max software in OBJ format. Figures 12, 13.

- From the photo models obtained in the Autodesk RECAP photo software, it can be exported in TPS format and then introduced into the Revit software by downloading point clouds. Sections in plans and elevations can be extracted from the 3D model introduced in Revit Figure 14. It is the reverse modeling process which consists in extracting from the 3D Modeling the 2D elements such as sections and facades and plans.
Figure 10. Photomodeling of the Didon statue in Carthage (Student work).

Figure 11. Photo modeling of the arcopallium of Carthage (Student work).

Figure 12. Photomodeling of a shop in Sidi Bou Said the 3D model was inserted into 3DSMAX (student work).
This student work involved the photo modelling of a shop in Sidi Bou Said carried out in the zephyr 3D software to introduce them to the 3D SMAX software in OBJ format. This allowed us to obtain plan and facade views in 2D. (Figures 12, 13).

This student work allowed the photo modelling of a station in Tabarka to introduce into REVIT.

Design processes based on large, interconnected databases seem significant today according to needs and developments. However, these distributed computational practices with strong potential at the crossroads of BIM and computational design are still not widespread. The scientific approach of the architect, as well as his interdisciplinary positioning, with the integration of skills, allows him to rationally take charge of all the technical elements concerning the design and development of tools and processes, as well as to formulate methodological reflections related to the questions raised by the objects of study [Figure 14].

Photo modelling of architectural details in Archaeology can constitute parametric modelling. Introduced in Revit, these photo modellings of architectural objects can be manipulated and be the subject of morphological restitutions of ancient monuments with a formal and dimensional chart taking into account the semantics of ancient architecture [Figure 15].
Heritage Building Information Modeling “HBIM” HBIM for Heritage Building Information Modeling was first used by Maurice Murphy (Murphy, Historic Building Information Modeling (HBIM) For Recording and Documenting Classical Architecture in Dublin 1700 to 1830, 2012). This term indicates a new way of modelling all existing buildings using a BIM process. It requires the generation of intelligent models that can contain and manage information. Models relate to all project components and include their geometric and identifying information and all physical properties that describe them in detail. The first attempts to return a BIM model of an existing building were related to historical heritage buildings. The goal is to create a database in which it is possible to insert the models created to disseminate information for various purposes. Information such as the geometric restitution of volumes, thermal analyses, etc. (https://www.accasoftware.com/fr/hbim-historical-buildings). This formalisation of knowledge will also have as a future objective the contribution to modelling, allowing to contribute to the development of the cognitive skills of the architectural designer in this field (educational objective) and, more generally, guiding the decisions and the conceptual interventions to update the built and urban heritage by a contemporary architecture in favour of a creative appropriation of the built architectural heritage and the quality of the built environment.

Ontologies and pre ontologies while in philosophy, ontology is the science of what is, types and structures of objects, properties, events, processes, and relationships, in computer science and knowledge management, an ontology is the specification of the conceptualisation of a domain of knowledge [19] (Phan, 2010). The term “ontology” appeared in cognitive science and computer science ten years ago. In its broadest sense, ontology is synonymous with theory or conception of reality. […] In philosophy, ontology is the science “of what is, of the kinds and structures of objects, properties, events, processes and relations in every area of reality”; in a broad sense, it is the study of “what could exist”.

Figure 15. Parametric model (student work).
[19, 20] (Smith, 2003) (Phan, 2010). Modelling knowledge requires having semantic structures (which relate to meaning and meaning) and representation formalisms to translate the complexity of human thought [21] (Vandecasteele, 2012).

Student work at the urban scale of the city of Sousse using aerial photographs, satellite images and photomontages to model the main monuments of the city, the street hierarchy and the atmosphere of the city and this to carry out the analysis of the site [Figure 16].

Figure 16. Aerial Photograph and site analysis (Student work).

Figure 17. Google Earth images of the city of Akouda and its section.
Figure 18. Akouda field extraction measures (student work).

From Akouda's orthophotographs, obtained from google earth, the terrain's sections, shapes, and measurements can be extracted [Figures 17, 18].
From the orthophotographs obtained from Google Earth, the field's sections, shapes, and measurements can be extracted. The volumetric architectural sketch is inserted into the site with the orientation and the urban environment [Figure 19].
In this work, the student modelled the buildings surrounding the land in 3D from google earth orthophotos and inserted his project into the site. We have an urban dimension to the project, which can help with architectural design [Figure 20].

6. Conclusion and Perspectives

This paper presented the results of our pedagogical approach at the National School of Architecture and Urbanism of Tunis through student work. If the traditional practice of 3D modelling, which consists of starting from the 2D plan, using sections and facades to develop a 3D model of the building, is widespread, our objective is to guide future architects and future archaeologists towards new practices based on the digitization of architectural and archaeological heritage using different 3D techniques such as photogrammetry and lasergrammetry and the use of satellite images obtained from google earth and the generalization of these methods for site analysis and the development of BIM and HBIM methods that use parametric models and artificial intelligence in the representation, study and diagnosis of pathologies at the architectural building level through collaborative platforms.

Our research perspectives include developing a design aid, particularly in the intervention on the architectural heritage.
using the HBIM and Digital Archaeology.

References


