The digitization of museum collections for the research, management and enhancement of Cultural Heritage

Sandro Parrinello

edited by

Digital & Documentation

Databases and Models for the enhancement of Heritage

Volume 1

PROSPETTIVE MULTIPLE
STUDI DI INGEGNERIA
ARCHITETTURA E ARTE

Sandro Parrinello

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Digital & Documentation

Databases and Models for the enhancement of Heritage

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The volume consists of a collection of contributions from the seminar "Digital & Documentation: Databases and Models for the enhancement of Heritage", realized at the University of Pavia on the day of June 26th, 2018. The event, organized by the experimental laboratory of research and didactics DAda Lab. of DICAr - Department of Civil Engineering and Architecture of University of Pavia, promotes the themes of digital modeling and virtual environments applied to the documentation of architectural scenarios and the implementation of museum complexes through communication programs of immersive fruition.
The event has provide the contribution of external experts and lecturers in the field of digital documentation for Cultural Heritage. The scientific responsible for the organization of the event is Prof. Sandro Parrinello, University of Pavia.

This publication is made with the contribution of DICAr, Department of Civil Engineering and Architecture of University of Pavia, through the joint research of the experimental laboratories DAda Lab - Drawing Architecture Document Action and PLAY - Photography and 3D Laser for virtual Architecture LaboratorY.

University of Pavia

DICAr - Departmen of Civil Engineering and Architecture

DAda Lab - Drawing and Architecture DocumentAction

PLAY - Photography and 3D Laser for virtual Architecture laboratorY

The event "Digital & Documentation" has seen the participation of professors, researchers and scholars from University of Pavia, Nanyang Technological University of Singapore, University of Rome "La Sapienza", University of Catania, Politecnico di Torino, University of Florence, University of Palermo, University of Chieti-Pescara "G. d'Annunzio".

University of Pavia

Nanyang Technological University of Singapore

University of Rome "La Sapienza"

University of Catania

Politecnico di Torino

University of Florence

University of Palermo

University of Chieti-Pescara "G. d'Annunzio"

The event is promoted by the Order of Engineers of the Province of Pavia and by the Order of Architects, Planners, Landscape Architects and Conservators of the Province of Pavia.

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Order of Architects, Planners, Landscape Architects and Conservators of the Province of Pavia

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Politecnico di Torino

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FOR THE RESEARCH, MANAGEMENT AND ENHANCEMENT OF CULTURAL HERITAGE

Abstract

The research project takes part of the pilot initiative "Create a network around your research idea", funded within the framework of the collaboration between Politecnico di Torino and Compagnia di San Paolo. The initiative promotes the research projects proposed by researchers of the Politecnico di Torino in collaboration with universities, companies and other entities of the socio-economic system located in Italy and in any other State Member of EU.
The research draws inspiration from BIM (Building Information Modeling) methodologies - more conventionally applied in the field of Construction Industry - to build a workflow capable of virtually reproducing 3D objects, integrating geometric and semantic information. The case studies are some small objects belonging to the collections of the Egyptian Museum of Turin and pursuing three different levels of knowledge: from the scientific research to the data management system up to the settlement of virtual platforms for dissemination.
The research project B.A.C.K. TO T.H.E. F.U.T.U.RE. - *BIM Acquisition as Cultural Key TO Transfer Heritage of ancient Egypt For many Uses To many Users Replayed* - tries to set up a new methodology in which the Information Modeling tools are used in an unconventional way, to build 3D models and linked databases of small objects, in particular belonging to museum collections and not publicly accessible. Inspired by Ministerial Decree n. 113/2018, entitled "Adoption of uniform minimum levels of quality for museums and places of culture of public belonging and activation of the National Museum System", we have reinterpreted the improvement objectives described in the document and associated them to the three defined macro areas, through the use of interoperable digital technologies.

Il progetto partecipa all'iniziativa pilota "Metti in Rete la tua idea di Ricerca", finanziata nell'ambito della collaborazione tra Politecnico di Torino e Compagnia di San Paolo, per promuovere i progetti di ricerca proposti dai ricercatori del Politecnico di Torino in collaborazione con università, aziende e altri enti del sistema socio-economico italiano e di qualsiasi altro Stato membro dell'Unione Europea.
La ricerca prende ispirazione dalle metodologie del BIM (Building Information Modeling), più convenzionalmente applicate all'industria delle costruzioni - per costruire un flusso di lavoro in grado di riprodurre virtualmente oggetti 3D, integrando elementi geometrici e informazioni semantiche. I casi di studio sono alcuni piccoli oggetti appartenenti alle collezioni del Museo Egizio di Torino, perseguendo tre diversi livelli di conoscenza: dalla ricerca scientifica al sistema di gestione dei dati fino al sistema di gestione dei dati. insediamento di piattaforme virtuali per la diffusione.
Il progetto di ricerca B.A.C.K. TO T.H.E. F.U.T.U.RE. - *BIM Acquisition as Cultural Key TO Transfer Heritage of ancient Egypt For many Uses To many Users Replayed* - cerca di impostare una nuova metodologia in cui gli strumenti di Information Modeling sono utilizzati in modo non convenzionale, per costruire modelli 3D e database collegati a piccoli oggetti, in particolare appartenenti a collezioni museali e non accessibili al pubblico.
Con specifico riferimento al Decreto Ministeriale n. 113/2018, dal titolo "Adozione dei Livelli Minimi Uniformi di Qualità per i Musei e i Luoghi della Cultura di Appartenenza Pubblica e Attivazione del Sistema Museale Nazionale", si è tentato di reinterpretare gli obiettivi di miglioramento descritti nel documento e associati alle tre macro aree definite, attraverso l'utilizzo di tecnologie digitali interoperabili.

Introduction

Many museums have huge collections as well as huge depots and storerooms where they store a remarkable number of historical artefacts. However, this wealth of objects could also represent a problem, from the management point of view, and a correct preservation as well as the widespread communication of museum collections are of utmost importance. The quantity and heterogeneity of small objects are very difficult to be managed, because they may be of too specific interest or their state of preservation is poor. The limited space available to exhibit collections means that many objects are stored without any real possibility of using them as an active part of the collection for their contribute to a general knowledge.

On the other hand, in recent years, museums have no longer been used just as "containers" of works, but are now used as places where knowledge is built, communicated, and shared in a complex system of relationships between subjects (institutions, curators, scholars, the public, visitors, the community, etc.), heritage (material, immaterial, collections, the territory, the landscape, etc.), and digital technologies (interaction, immersion, virtual and augmented reality, etc.). This change of view approach to museums is also acknowledged in Italian laws, in which museums are now conceived as "goods for use" available to the community[1]. New kinds of museums are being designed to promote knowledge for the public and the scientific community[2].

Within this scenario, each act made to conserve the heritage is naturally an act of communication, derived from a new "inclusive" vision of cultural goods, even in a museum, by pointing out a redesigned role and the subsequent responsibility towards the community. According to this, although the preeminent task of museums in the past was to conserve and increase the heritage of the collections, museums are now called upon to interpret a process of "democratization", not only of promoting participation, but also of collaborating in emancipating the public, where knowledge in the past was reserved for a chosen few, in general composed of specialists. Starting from the state of the art of representing knowledge through a digital model, this project is aimed at finalizing for the management, monitoring and fruition of museum objects. The main purpose of the proposed research is to build up a methodology that will be able to virtually reproduce 3D objects by integrating geometric and semantic information that will allow museum collections to be effectively used for management procedure; at the same time, those digital products can be valorized for a variety of possible visitors. In other words, the research will focus on the optimization of 3D recording techniques (metric surveys and modelling) and 3D data integration by offering a user-friendly way of sharing complex information at different levels of information. The purpose of the research in particular is to make use of the (Building) Information Modeling methodology for unconventional purposes, applying it to different kinds of small objects.

State of the art

The relationship between cultural heritage, digital technologies and visual models involves an increasingly wide area of research, which is oriented towards the renewal of archives and museums for the preservation and promotion of culture. In this respect, very recent research activities are the result of the progressive strengthening of digital technologies, but above all, they are determined by the requirements of a new audience, which is increasingly "digital" and thus requires museums to update their means of communication[3].

As far as the use of BIM applied in the Cultural Heritage field is concerned, no specific approach has been fully explored, because of some criticalities. A total absence of archeological element libraries, as well as the stiffness of the 3D modeling of unconventional shapes are the major criticalities that have partially been faced by the Scientific Community. However, we are firmly convinced that H-(Historic)BIM applications

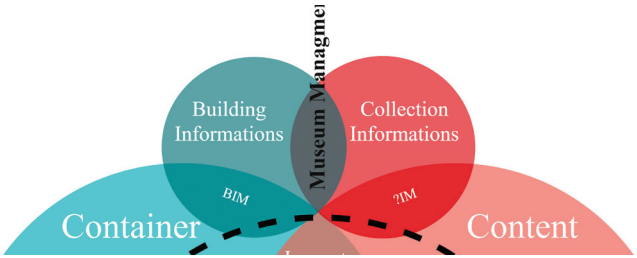


Fig. 1 - Relationship between the elements that are part of the museum experience.

could also be explored in terms of accuracy, infographic representation and above all data enrichment[4]. By the way, with regard to the use of BIM in the context of cultural heritage with reference to small objects, no prior experience exists on the subject due to some structural problems, mainly due to the rigidity involved in the 3D modelling of unconventional forms.
More generally, the digitization of collections, whether 2D or 3D, represents the first step for establishing a project perspective aimed at the digitization of museum heritage. In recent years, some research has been conducted on the digital survey and modelling of models and maquettes preserved in museums[5] as well as the enrichment of data concerning these models[6].
The research projects related to these themes are considerably broader in their scope: the European project MINERVA (2002/2005) was already aimed at facilitating the creation of a common vision through several actions and programmes to improve the accessibility and usability of cultural heritage on the Internet. Subsequently, the MICHAEL and MICHAELplus (2004–2008) projects created a network of national databases that allow access to Cultural Heritage through the adoption of digital resources of cultural and scientific interest. In 2008, with the birth of Europeana, the idea of a European digital library was affirmed. This acted as a collector for contributions already digitised by European institutions. Over the years, guidelines and standards have been produced European Data Model (EDM) documentation to facilitate data collection and segregation. Additionally, several European projects have worked towards the digitization and 3D documentation of historical artefacts (3D-COFORM). Among these, CARARE (2010–2013) and 3D Icons (2012–2015) were designed to support various cultural institutions interested in providing digital cultural content (archaeology and cultural heritage) through Europeana. At the same time, some digital infrastructures for archaeological research were financed for the management and integration of archaeological data at the European level, (i.e. ARIADNE, 2013–2015). Finally, the last calls (2018–2020) within European policies address the management of digital resources and advanced digitization, also aimed at the narration of objects, then projected towards the communication of cultural heritage. Several approaches have been tested in order to enable interaction between 3D environments and users, based on annotation systems. Platforms have been developed for document sharing and management, methods and techniques for multi-level annotation, metadata and vocabularies for the declaration of interpretative instances. As a starting point, the annotation system is based on ontologies, using a shared environment, thanks to the possibility to annotate different aspects of a text overlaps with metadata models and ontologies used for annotation, and related values vocabularies, but also with techniques for producing annotations[7]. The International Committee for Documentation (CIDOC) of the International Council of Museums (ICOM) developed a Conceptual Reference Model (CRM) that represents the outcome of more than a decade of work in standards development[8]: this was the reference ontology chosen in the framework for the ARIADNE project, according to the first aim related to the implementation of interoperability across archaeological data at the European level.
The communication aspect and the dissemination of initiatives aimed at the digitization of museums and museum heritage has led to the development of other projects: V-MUST (2011–2015) has created a network of excellence on virtual museums, providing information on the state of the

art and future developments. The focus on communication and enhancement of cultural heritage is also evident in the GRAVITATE project (digital platform for the re-unification, re-association, and re-assembly of heritage artefacts) and INCEPTION project (aimed at creating an innovative process for the 3D modelling of cultural heritage through an inclusive approach for 3D reconstruction of time-dynamic artefacts). These projects are also sustained by support and coordination actions, such as Virtual Multimodal Museum (Vi-MM) that support the main organisations working in the virtual museums to promote the development of high-quality policies to aid decision-making processes.

Regarding to the more technical issues of digitization, 3D metric survey techniques are today able to generate dense and accurate point clouds that can be used in the 3D modeling phase, which is influenced to a great extent by the knowledge of the breaklines that define the discontinuity of the shapes of an object (such as the Temple maquettes chosen as case studies and other small archeological finds). Breaklines can be manually surveyed but this approach is time consuming; automatic breakline surveys were tested in the past, but no many efforts were made and only a few results have been published till now. The existing solutions usually try to overcome this problem by increasing the density of the point clouds and reducing the blurring effect of automatic modelling tools. This solution requires high computation capacities and a huge amount of storage memory. Therefore one of the goals of the research refers to the opportunity to define the best acquisition methodology that ensures the possibility of obtaining accurate 3D models (and retopologized, according to a mesh simplification) in such a way as to be easily shared with other platforms and ready for web fruition.

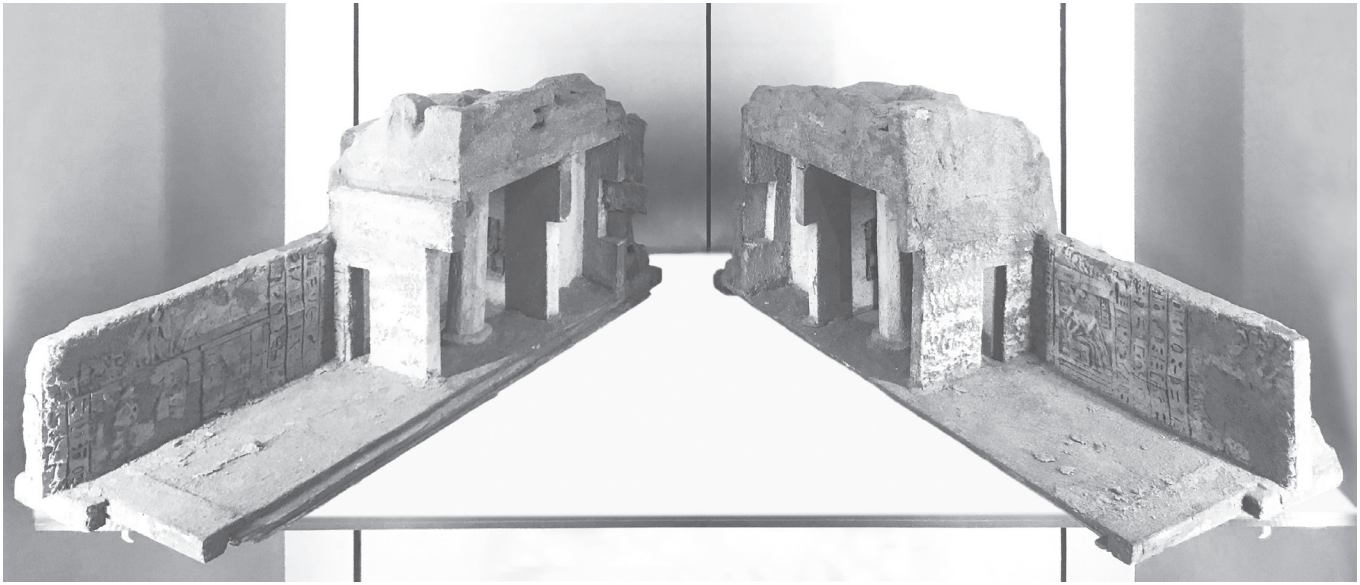


Fig. 2 - Physical model of the Roman temple of South Tafa divided into two halves, about 1820.

Description of the case studies

Museo Egizio has several physical models (maquettes) of Nubian temples from the geographical region between Abu Simbel and the Aswan dam; these refer to different historical periods. The museum contains 11 physical reproductions of Nubian temples, (Debod, Tafa North and South, Beit el-Wali, Kalabsha, Dendur, Gerf Hussein, Dakka, Derr, Abu Simbel, and Gebel Adda), initially located between Abu-Simbel and the Aswan Dam, which, after the flooding of the Nile, were dismantled and reassembled in safer sites. The models, dating back to the early 1800s, are generally composed of two halves (that, if opened, allow us to observe the interior; the authorship of the models is attributed to French sculptor Jean-Jacques Rifaud (1786–1852) due to observed similarities with some of his drawings from the time[9]. Most of these maquettes are conserved in specific storerooms inaccessible to the public.

Rifaud's models probably came to Livorno from Nubia between 1819 and 1823 and was subsequently transported to Turin where they became a part of the Egyptian museum's collection. The Egyptian museum, with its wooden models, offers several case studies to study the experimental procedures. Furthermore, these models represent complex elements, because they form miniature architecture models and not merely only small objects. The first wooden model that would be worked on is the representation of the minor temple of Abu Simbel (Nefertari's temple); it is composed of assembled wooden elements covered with a mixture of sand and wax. Its size is approximately 80 x 60 x 35 cm[10].

Fig. 3 - Half of the physical model of the Roman temple of South Tafa divided into two halves, about 1820.

Fig. 4 - Physical model of the Ptoleimaic-Roman temple of Thoth in Dakka divided into two halves, about 1820.

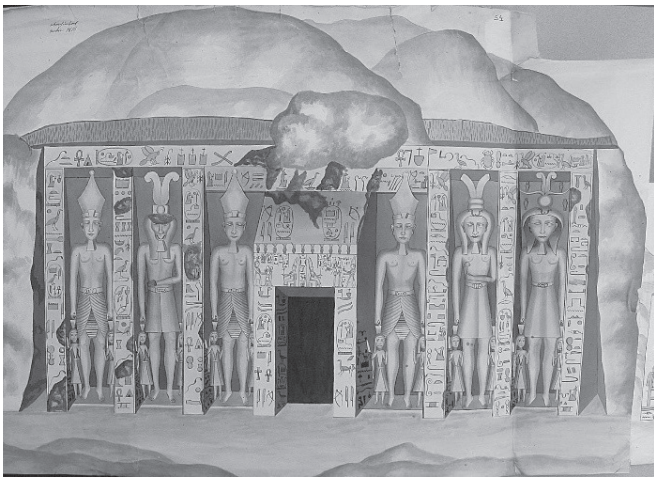
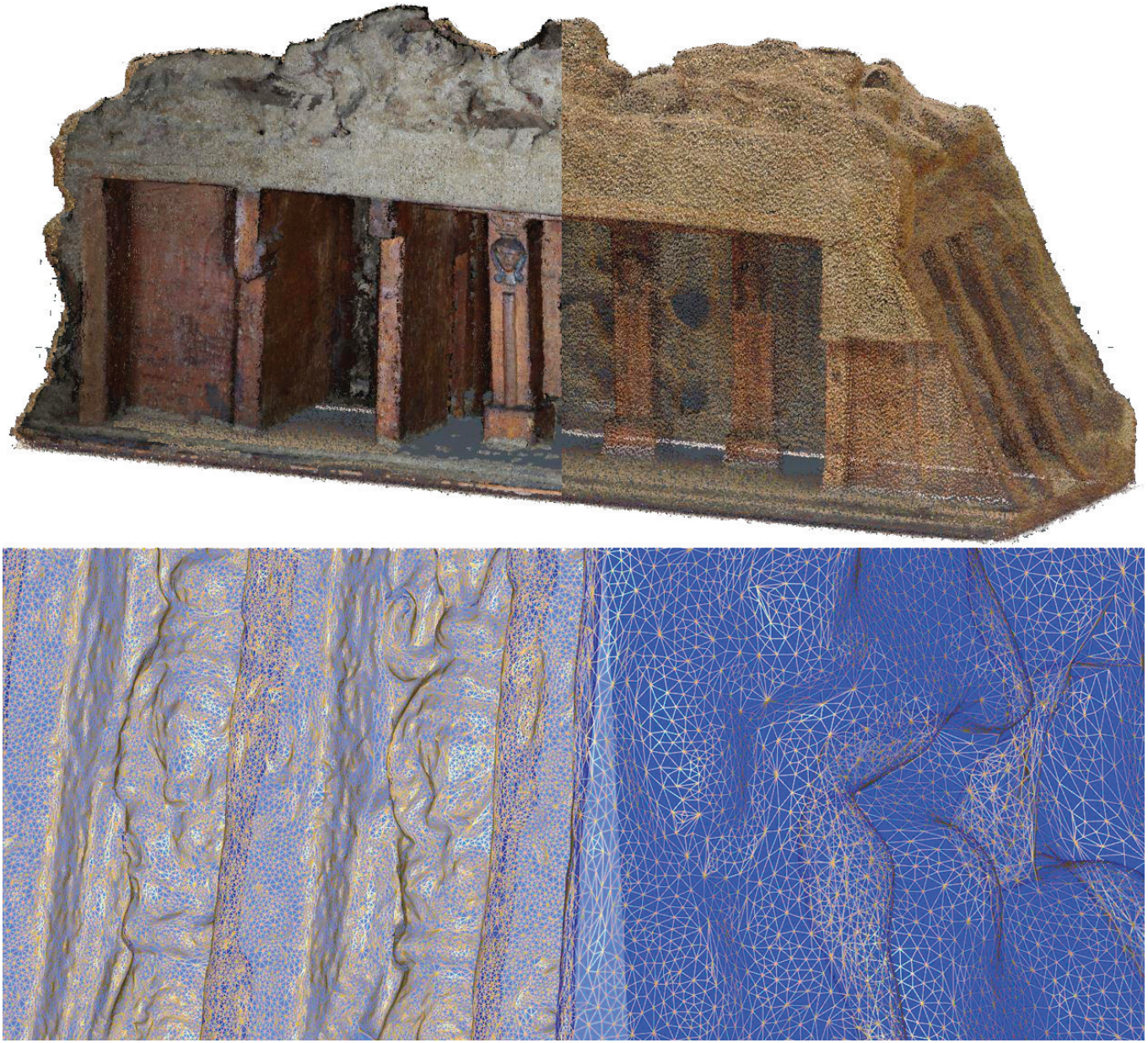


Fig. 5 - Drawing of the facade of the minor temple of Abu-Simbel. Author: Jean-Jacques Rifaud.



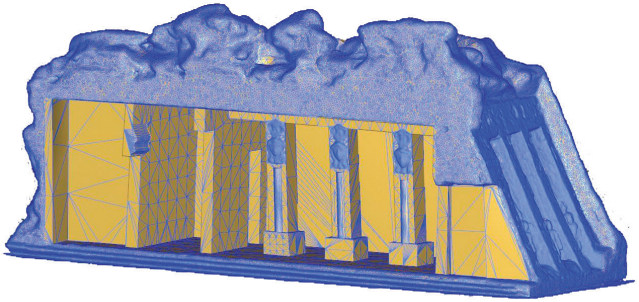


Fig. 6 - In the previous page. Top left, point cloud from photogrammetry; top right, point cloud from LiDAR. Below, some details of the model topology once the surface has been created.

Fig. 7 - In this page. The final model is the result of a weighted union between different clouds. The internal parts have been reconstructed assuming geometric surfaces that better approximate the surveyed shape.

Research activities

The research activities carried out in the first year consist of several phases:
- Documentary research and metric survey of the collections.
- Analysis, digitization and retopology of the acquired models.
- Semantic enrichment of metrically detected models.
- Critical analysis on methods and tools that can be used in the prefiguration of a web portal for increased and facilitated communication of the characteristics of museum objects.

The above lists the main steps validated on the first case studies examined, the temple of Nefertari in Abu Simbel and the temple of Taffa Sud.
Considering the aim of the research project, in the first phase of survey and digitization of the museum artefact, a metric survey accuracy of 2 mm was considered acceptable. Therefore, it was possible to take into consideration some detection techniques, generally excluded in the field of higher accuracy. For each sub-model, three different types of acquisition were applied:

- terrestrial laser scanning (TLS) with a flight time scanner (Faro Focus3D X 330).
- portable laser scanner (Faro Freestyle3D).
- photogrammetric survey using a DSLR camera (Canon EOS 5DS R) fitted with a Canon lens (fixed focal length 24 mm and manual focus).

The acquisition systems listed above provided point clouds with different characteristics; these differ in terms of density, resolution and presence of gaps (shadow areas not described by the clouds). The final dataset was then generated by the balanced integration of the three previously acquired datasets.
The analysis of the morphological complexity of the model led to some topological choices in the mesh modelling phase, describing the whole model by means of three different types of polyhedral surfaces. A type (1) formed by a few polyhedra for the representation of the internal flat parts; a type (2) denser in faces for the description of the internal and external sculptural parts; a last type of mesh surface (3) for the less accurate description of the irregular external part that simulates the rocky mass.
In parallel to the acquisition phase, the research on new methods and tools for the semantic enrichment of 3D models was carried out. For the information stratification, the Visual Programming Language (VPL) was experimented with the software Grasshopper. The first activities were carried out by linking the acquired 3D model to a spreadsheet, exploring the possibility of linking some general information to the model, obtained from the inventories made available by the Egyptian Museum.
The model was then enriched with the first data collected and appropriately converted for web visualization through the use of dedicated plug-ins in VPL environment.

Achieved results

The main results obtained from the beginning of the research project are shown below:
Definition of the procedure for the acquisition and digitalization of the museum object: on the basis of the tests carried out on

Fig. 8 - 3D model textured visualization of the Temple of Nefertari in Abu Simbel.

the first artefacts, a procedure was defined for the acquisition and digitization of the museum object, which involves the integration of three detection techniques for the definition of a dataset whose output is shown in the 3D object: an excellent compromise was reached between the measurement speed and the subsequent creation of accurately geometric models, correctly re-tested (low number of triangles on large flat surfaces, greater segmentation in more irregular areas) and ready to be semantically enriched with useful information for the management of the property and for possible use by visitors. This optimised procedure will be systematically used for the remaining finds that are the subject of the research.

Definition of data enrichment procedure using VPL technology:, the use of the 3D model in the field of communication has been tested through the use of VPL technology that allows both the semantic enrichment of the object and its visualization on an implementable web portal. The information enrichment of the 3D object must have a multidisciplinary character and must coexist within one or more databases dedicated to the individual disciplines and/or management areas concerned.

The first year of activity led to the identification of technologies and procedures that had not been explained in the project proposal, in particular the use of VPL technology for data enrichment of the digital model directly related to an Information Modeling environment. Another important and innovative issue is represented by the identification of the formal ontology to be adopted in the development of the research, to organize the data of the digital model. This allows to work on different types of data to be integrated into the digital model, including:

- Historical-artistic data related to the wooden model: information related to the wooden model and its value as an object belonging to a collection and its historical events (origin, dating, materials, uses, purposes, ...).
- Historical-artistic data of the represented object:

information about the architecture represented by the wooden model, from which it is possible to access information of a graphic, textual, numerical nature that tells the story of the represented temple (historical images, views of travelers, previous surveys, the procedures of UNESCO campaigns for the recovery of temples, new locations, etc. ...)

- Data concerning the management and maintenance of the object as part of a collection: information on the object management (the model) is generally contained in paper schedules stored in the museum archive. The digitization of the works and the consequent opportunity to enrich these virtual models with technical and specialized information allows the redesigning of the usual procedures for filling in the forms, making the cataloguing process more efficient.

In fact, the growing activity of digitization and sharing of museum collections makes it necessary to organize databases based on an appropriate computer ontology, i.e. a series of conceptual distinctions - impossible without the development of a semantics and a lexicon provided to computers by (human) programmers - that are transversal and interoperable.

For this reason, the next development of research will focus on the definition of an ontology based on the CIDOC-CRM (CIDOC Conceptual Reference Model) standard for the documentation of cultural heritage in museums collections.

Potential impacts and future developments

The methodological approach described above will make it possible to obtain:

- a rational use and classification of data concerning museum collections;
- possibility of a greater exchange and sharing of data with other museums;
- integration of different archives;
- long-term preservation of the data.

The complete novelty of the study in progress is to be found in the development of a prototype system that virtually reproduces objects and collections (content) in relation to its museum (container) allowing users to operate on the system of relationships content/container of the exhibition space. This issue is thought to support virtuous procedures of automated control of environmental requirements contained in the object schedules and in the building schedules, most commonly used in museums.

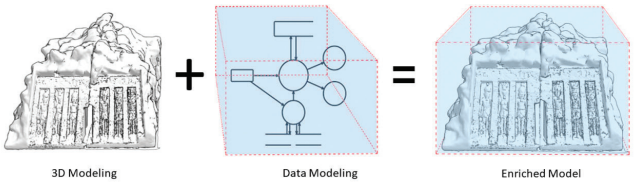


Fig. 9 - The procedure involves both the modelling of the shape mainly through topological control and the data modelling linked to the object through the setting up of a digital database.

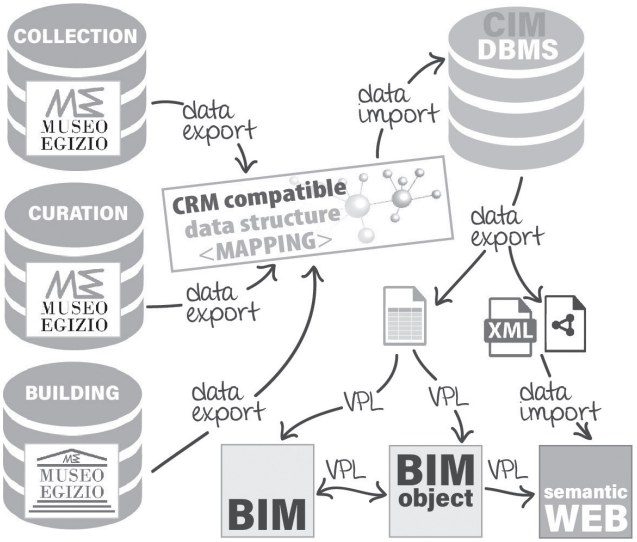


Fig. 10 - Collection Information Modeling (CIM) data management system and possible outcomes.

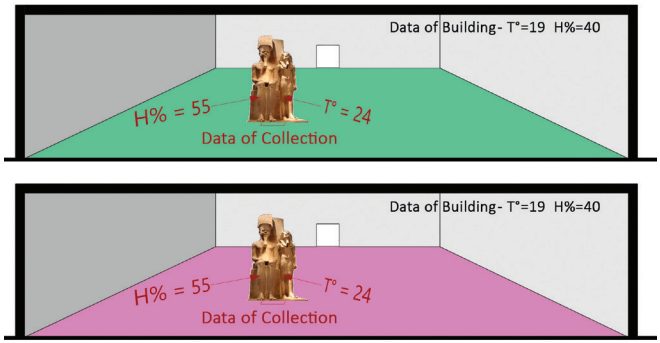


Fig. 11 - Direct dialogue between object and building information. Above, the object information relates positively to the building parameters: this means that the object can be located in that room; below, the object information relates negatively to the building parameters, so the object can not be located in that room.

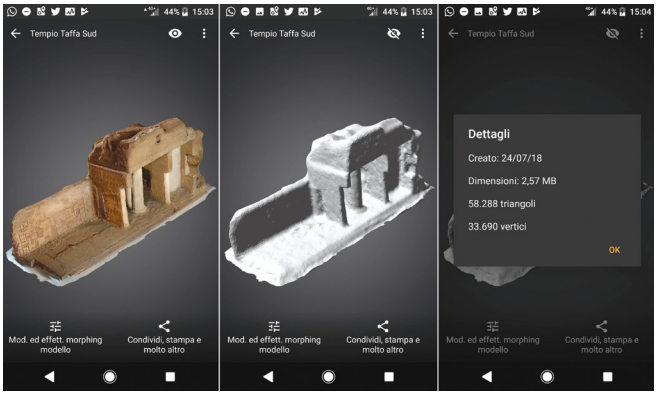


Fig. 12 - Visualization of a part of the Temple of Taffa Sud acquired with low cost technologies: through an application for smartphones it is possible to digitalyze the object of a collection, storing metric and colorimetric data associated with a low poly virtual model, easy to be explored and shared on web platforms.

The presence of a BIM model of the building that hosts the objects of the collections (museum), could allow, in a virtual environment, to highlight any inconsistencies between the environmental needs of the objects to be exhibited and the real conditions possessed by the exhibition spaces of the building. The construction of this system, suitably designed, will facilitate the scientific/cultural dissemination of the objects present in the museum deposits and will facilitate the future management and care of the museum collections: the experimental nature of the research is therefore confirmed, aimed on the one hand at optimizing the management procedures through structured databases, and on the other hand at making part of the data available for consultation, further enriching the visitor experience (virtual exploration can also be remotely used according to a view to maximum social inclusion).

Through the construction of digital models for management, maintenance, conservation and dissemination purposes, the objectives set for 2020 by the European Community's development programmes will be achieved, tackling problems related to the growing need to create protocols for documentation and management of the architectural heritage in order to organise information systems relating to Cultural Heritage in a virtuous manner.

The longer term impact is the digitization of larger collections accompanied by the virtual reconstruction of the environments that contain them, capable of foreshadowing design hypotheses of preparation in relation to the characteristics of the exhibition space.

In this regard, the process of digitization and collection of data useful for management purposes will be followed by reasoning on a wise use of recent digital technologies for popular purposes, in the direction of greater inclusiveness. Digital environments are particularly attractive not only to the new generations, but also to those of orevision of the

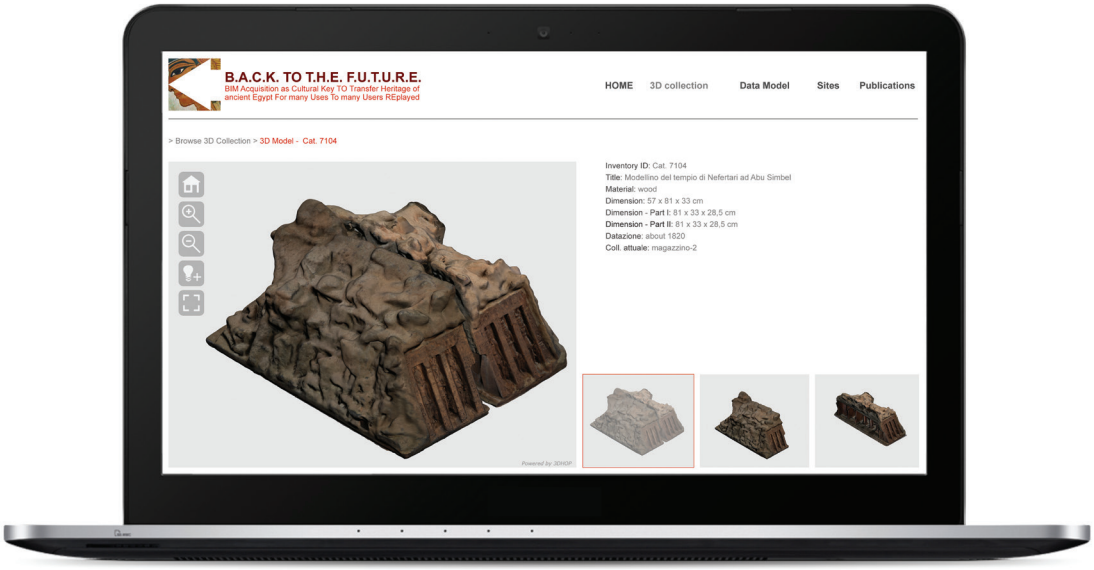


Fig. 13 - Interactive Web presentation of high-resolution 3D models.

installations are countless. A wise rigour is therefore needed in their applications for the creation of digital envlder age: the potential of the application of innovative technologies related to museum collections and the necessary radical ironments that leave time and ways for a direct contact with the artworks; at the same time, it's crucial to create effective opportunities to remotely obtain some information tools to prepare oneself for the face-to-face confrontation with the masterpieces, rather than tools for ex-post in-depth analysis, avoiding the risk of a simplification that could lead to trivialisation[11].

Notes

[1] D.L.42/2004: Capo I-Titolo II - Fruizione del patrimonio culturale.

[2] Art.1 "Definizione e missione del museo" of the D.M. 23/12/2014, titled "Organizzazione e funzionamento dei musei statali"; UNESCO 2003, Convention concerning the Protection of World Cultural and Natural Heritage.

[3] Cf. Antinucci 2014, p.178.

[4] Cf. Apollonio, Gaiani, Zheng 2012.

[5] Cf. Bianchini 2007.

[6] Cf. Hervy et al. 2012; Hervy et al. 2014.

[7] Cf. Tommasi Vitali 2013.

[8] Cf. Crofts et al. 2011.

[9] Cf. Bruwier, Claes, Quertinmont 2014.

[10] Cf. Einaudi 2016.

[11] Cf. Lampis 2018.

The topic of Documentation, which increasingly involves the field of drawing and architectural survey, uses digital technologies and new multimedia communication systems to acquire, analyse and disseminate the value of our historical heritage. The adoption of static or dynamic images to support this investigation is one of the aspects on which researches related to the subject of documentation are most frequently concentrated.
This volume, transposing the result of the first conference day of the cycle "Digital & Documentation", summarizes some research experiences of professors and experts of representation areas in Italian universities, illustrating through drawings, architectural surveys, 3D models and virtual interactive spaces how the "Digital" has become part of our common language, as a communicative system to understand new feature of configuration of heritage. The application of digital technology to Cultural Heritage moves towards the production of information systems to support greater usability and communicative clarity. The contribution exploits theoretical reflections, examples on existing museums and utopian virtual spaces, in order to demonstrate the multiplicity of applications in various contexts and to propose points for reflection in future research activities in this field.

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