Digital Archives for Academic Heritage: Tools and Processing Environments for the Museum Metaverse and Scientific Dissemination

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Digital Archives for Academic Heritage: Tools and Processing Environments for the Museum Metaverse and Scientific Dissemination

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Abstract

In recent years the digital visualisation techniques, including 3D digital models of indoor spaces, saw an exponential increase in their applications, both in the fields of Architecture, Engineering and Construction (AEC) and of Cultural Heritage (CH). This growth is mainly due to the increasing affordability of tools for the acquisition and elaboration of three-dimensional digital survey/data management and to their increasing ‘user friendliness’.
The research proposes a further step on research started some years ago by our group about the exploration of indoor mapping for the creation of the 3D virtual museum of our Institution, starting with the realisation of a virtual model of the university’s spaces (departments and halls). At first, the virtual museum will host the Curioni Digital Collection, which consist of circa 140 wooden models of building details, bridges, tunnels, and vaults designed by prof. G. Curioni during the second half of the XIX century as teaching aids for the Construction and Structural Design classes. A comparison between two main tools to support management and diffusion of geometrical, alphanumerical, and topological data will be given (Matterport and Unity). The parallel approach considering two tools is to provide a digital twin of a real collection placed in a real space, and, on the other hand, to use a real historical university space, virtualized, to host a virtual collection.

1. Introduction

Several studies address the issue of cultural assets preserved by universities and show in many cases a significant ‘patrimonial status’ that is not always matched by an organisation that can best guarantee its use and valorisation (Halle, 2000).

In addition to the preservation of its historical and archival heritage, the Politecnico di Torino has been engaged in processes for the dissemination and communication of this knowledge and information for many years. These processes re achieved through the use of dedicated management methods and IT tools that facilitate the sharing of these resources across the university, which is comprised of various components, including the library and museum system, as well as academic departments.

The contribution, through some limited explorations, highlights the role of links that deserve to be supported in order to improve the actions of preservation and knowledge of technical historical heritages. This can be achieved by making their value alive through conceptual and accessible supports that exploit the performance of the most advanced digital technologies.
The paper proposes a further step on research started some years ago by our group about the exploration of indoor mapping for the creation of the 3D virtual museum of our Institution, starting with the realisation of a virtual model of the university’s spaces (departments and halls). At first, the virtual museum will host the Curioni Digital Collection, which consist of circa 140 wooden models of building details, bridges, tunnels, and vaults designed by prof. G. Curioni during the second half of the XIX century as teaching aids for the Construction and Structural Design classes (Bocconcino et al., 2023; Bocconcino, Vozzola, Pavignano, 2023).

This project will be hosted by the new online archives of Politecnico di Torino (collezionistorichepolito), launched in 2020 and still under expansion.

2. Museums in the digital domain: a state of the art

In 2022, the Extraordinary General Assembly of International Council of Museums, ICOM, approved the new museum definition. It refers to the museum as «a not-for-profit, permanent institution in the service of society that researches, collects, conserves, interprets and exhibits tangible and intangible heritage. Open to the public, accessible and inclusive, museums foster diversity and sustainability. They operate and communicate ethically, professionally and with the participation of communities, offering varied experiences for education, enjoyment, reflection and knowledge sharing» (ICOM). The United Nations Educational, Scientific and Cultural Organization, UNESCO, define museums as «more than places where objects are exhibited and conserved»; still «museums can play a leading role in bolstering the creative economy locally and regionally. Museums are also increasingly present in the social sphere, acting as platforms for debate and discussion, tackling complex societal issues and encouraging public participation» (UNESCO). Both ICOM and UNESCO highlight the social function of museums, especially with respect to accessibility, inclusion, and public engagement; still, they point out that museums are places where cultural heritage (CH) can be experienced (Windhager et al., 2019). To improve all these functions, especially the differed experience of CH, in the last decades we observe a predominant evolution of digital tools and the interconnection between physical and virtual museums arose as one of the main topics of development and debate (Hamma, 2004; Parry, 2005; Parry, 2007; Marty, 2008; Marty, 2011; Marty and Buchanan, 2022; Taormina and Baraldi 2022).

This has been made possible by the exponential increase in the applications of digital visualisation techniques, including 3D digital models of indoor spaces, in recent years. These techniques have been used in the fields of Architecture, Engineering and Construction (AEC) and of CH (Parrinello, 2019; Pei and Yi. 2022.). From a practical standpoint, this growth can be attributed primarily to the declining costs of tools for acquiring and processing three-dimensional digital data, as well as their increasing accessibility at all levels.

This has led to the definition of different approaches for virtual museums, based on the used digitization procedures (Table 1). The first one is based on the digitization and on the online dissemination of the heritage preserved in the museums; another one is based on the digitization on the online dissemination of the museums; a third one is based on the 'born digital' concept and provide an unrealistic virtual space, with no connection to reality, used to define a virtual 'container' for digital copies of the artefacts to be show (Baloian et al., 2021). There is a subtle difference between those three approaches since the first one in focused on the heritage, the second one on the museums, the third one on the virtual container and on the heritage.

Types of digitization	Digitization on the museum	Digitization of the heritage	Unrealistic virtual
Outputs	Virtual tours	Digital repositories	Design of new spaces
Interactions	Virtual walks	Digital exploration	Digital exploration

Table 1. The three different types of virtual museums based on the digitization procedures.

These approaches can be merged as well as 'live' online on three parallel tracks (Rossi and Panciroli, 2019). Examples of the initial path, namely the digitisation of the heritage of museums, can be observed in the British Museum in London, UK, and the Rijksmuseum in Amsterdam, the Netherlands. Both museums utilise their websites to offer digitised collections, which are sometimes incorporated into a storytelling programme.

The British Museum provides users with the option to navigate through its collections and presents a multitude of files pertaining to individual artefacts (Figure 1a, b, c).
Conversely, the Rijksmuseum offers a series of narratives pertaining to specific themes. Each story presents an audiovisual tour focused on a specific topic (Figure 1d, e, f). Both examples do not involve the digitisation of any additional material, with the exception of images of each artifact.

With regard to the alternative means by which museums might gain entry to the digital domain, it is possible to identify the concept of virtual tours as a potential avenue for exploration. Examples of such initiatives can be found at the Louvre in Paris, France, and the Museo Egizio in Turin, Italy. In both instances, the museums utilise digital tours derived from 360-degree images to provide users with 3D explorations of specific rooms and exhibitions.

The Louvre offers thematic itineraries, which include plans, 3D tours and files on individual heritage items, all accessible within the same virtual environment (Figure 2a, b, c, d).

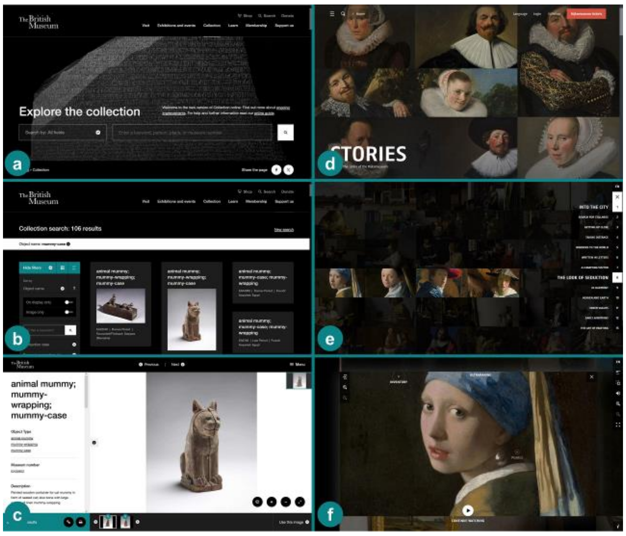

Figure 1. Museums in the digital age: digitization of collections and artifacts.

Conversely, the Museo Egizio employs a 3D virtual tour, wherein data enrichment is managed both within the same environment and externally, via Sketchfab for the 3D reconstruction of individual artefacts (Figure 2, e, f, g, h). In this case, the integration between virtual tours and is trivial.

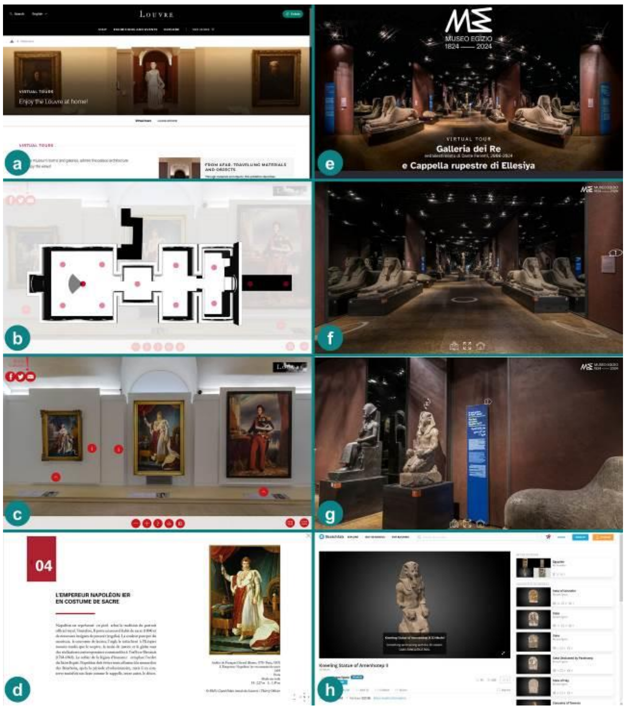

Figure 2. Museums in the digital age: enriched virtual tours with digitized heritage hosted on external repositories like Scketchfab.

Examples of the third type of virtual museums might not be so common nowadays, but they could be useful for gamification experiences (Besoain et al., 2022). Moreover, this kind of virtual museums can be implemented in the metaverse, to define collaborative learning environments (Kang et al., 2022), thus promoting one of the missions of museum.

Cited examples provide a partial view on the wide panorama of digital museums. We can find other kinds of digital interpretation, such as AR/VR/XR that can be used on-site and on-line (Galizia et al., 2019; Spallone et al., 2024), virtual ‘buildings’ representing ‘non-real’ spaces (or invented digital spaces) rather than real museal buildings (Santagati et al., 2020; García Gutiérrez and Ruiz López, 2021).

2.1 Science of representation and virtual museums

The examples presented in the previous paragraph do offer some interesting hints on the role of the science of representation within the context of digital/digitized/virtual museum. On one hand the science of representation does provide the theoretical framework for the constitution of digital museums: its statutes, in fact, do support the conceptual phase of museal digitization. On the other hand, it also offers its specific tools for digital survey and 3D modelling. In fact, as previously introduce, in recent years museums can rely on many different declinations of ‘digitization’. Among all the possibilities offered by the market and by the scientific panorama, indoor mapping systems are becoming more and more popular) (Bonfanti et al., 2021). In conjunction with such evolution, we assist the rising demand of digital twins in many fields of research, especially in those related to the creation of virtual 3D ‘places’ for dissemination and interaction between museum institutions and their public. This is even truer after the COVID-19 pandemic which forced many cultural institutions to explore new ways to disseminate their heritage at all levels (King, et al., 2021, Marty and Buchanan, 2022). The use of digital models can be characterized as two-fold, schematics, and visualization. On the one hand, schematic model applications include creating as-built models for monitoring of construction processes and building conditions. On the other hand, visually appealing virtual models of cultural and historical sites enable people to experience them remotely (Lehtola et al., 2017).

In our research we focus on indoor 3D mapping. It can be accomplished using several different techniques, including photogrammetry (Shao et al., 2015), depth camera (Henry et al., 2012) and laser scanning (Lee et al., 2013). While applications of virtual environments have been reported for several disciplines, for example, cultural heritage (Ogleby, 1999; Portales et al., 2009; Anderson et al., 2010), architecture and construction (Herwig and Paar, 2002; Fassi et al., 2011), the 3D models used have typically been produced by combining manual modelling techniques with 3D data (Fassi et al., 2011) or 3D reconstruction has been applied for producing partial models of larger targets (Portales et al.,2009; Virtanen et al., 2015). Specifically, we propose an application of Matterport (Schults et al. 2023) and Unity (Pernas- Álvarez and Crespo-Pereira, 2024) softwares to define dynamic representations of a portion of the online museum of our university.

3. Methodology

Until a few decades ago, when thinking about the creation of a new exhibition space where artefacts of any kind could be collected and shared, the dialogue was primarily between museology and museography, understood in its most common sense, i.e., as the design of spaces. Nowadays, the centre of gravity of the discussion has shifted towards the possibility of using digital and multimedia technologies, which contribute to a new and continuous experimentation with innovative formulas of fruition, suitable for new scenarios and different public experiences. Today, the museum is both an actor and a privileged interlocutor in interpreting and developing the paradigms of modernity in the era of digital transformation (Cataldo et al., 2023).

The introduction of digital technologies for the dissemination and sharing of cultural heritage is bringing about a significant paradigm shift in the field of museology: the museum’s digital twin is understood both as a container of objects and as a container of content housed and displayed within it. The digital model no longer serves the sole purpose of preserving the artefact but becomes a model that enables a mixed sharing and dissemination offer, both in-person and remotely, to establish a new dialogue between visitors, container/environment, and content. Within this scenario, the museum is configured as an accessible, inclusive environment characterized by storytelling customized to the different types of users and visitors.

It is within this context that the steps of the research conducted move, i.e., the possibility of sharing and making accessible the collection of Prof. Curioni’s wooden models kept in some rooms of the Politecnico di Torino, which are not accessible to most people. To make the premises and consequently the artefacts of the Curioni collection accessible to a heterogeneous public, whether an academic public of scholars, researchers, or students, or a public of the merely curious or those interested in the models, two different paths were taken, both aimed at the realization of the virtual museum:

a. the digitisation of the University’s spaces by means of photogrammetry, to create a virtual tour where one can explore the University’s rooms where the models are stored and interact with the models via connection to an external visualization and navigation platform. To realize the tour of the University, Matterport technology was used.
b. the creation of a virtual museum, modelled in the Unity environment according to the principles of museum design, where thematic rooms will be set up in which virtual models of the collection will be displayed, which can be explored and used by users to answer thematic questions.

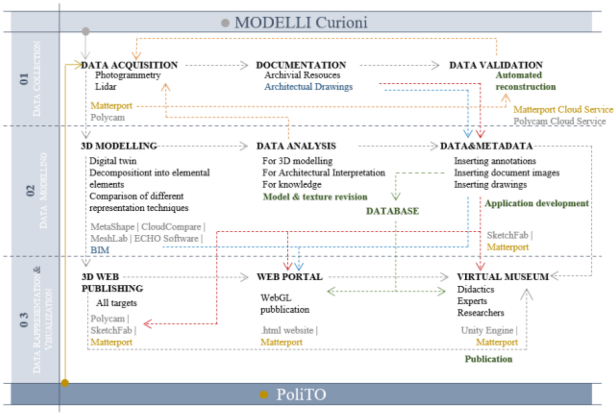

Figure 3. The final applied process combining automated reconstruction in Matterport with Unity environment.

A comparison between two main tools supporting the management and dissemination of geometric, alphanumeric, and topological data (Matterport and Unity) will be presented. The parallel approach between the two tools is to provide a digital twin of a real collection located in a physical space and, on the other hand, to use a real, virtualized historical university space to host a virtual collection. For both types of processing, the methodological approach, including data acquisition, processing, validation, and sharing, is illustrated in Figure 3.

The first part of our research was based on the photogrammetric survey of the rooms housing part of the Curioni collection. The initial phase of room acquisition was carried out using an Insta360 ONE RS camera, which is capable of taking 21MP 360° photos. The combination of the 360 cameras with the Matterport working and sharing environment allowed us to create a virtual tour of the surveyed environments with a reduced number of frames.

Starting with a photogrammetric survey, with a scan every 1.5m, and ensuring overlapping areas at the passages between rooms, we created the virtual tour of part of DISEG - Department of Structural, Geotechnical, and Building Engineering, covering about 200 sqm of space including rooms and distribution areas. This involved 22 photo shots, approximately 45 minutes of field survey, and 90 minutes of post-production within the Matterport work environment. The processing of the scans in Matterport is highly automated, utilizing a cloud computing service associated with the web environment (Figure 4).

Figure 4. Displaying the survey of part of the DISEG in Matterport. Survey carried out by Engineer Xhena Oparaku and Engineer Emanuele Ricchielo in May 2024.

Matterport offers a platform that allows users to create and share immersive 3D models of physical spaces. Visualizing physical spaces in a virtual environment is particularly advantageous.

The Matterport system is a highly integrated commercial indoor mapping system that combines a 3D measurement tool with a dedicated cloud-based service (Virtanen et al., 2018). The main products of the system are panoramic images and a 3D model of the environment (Figure 5).

Within the virtual model obtained from the photogrammetry, where the physical models of the Curioni Collection have also been inserted, it is possible to associate links to the virtual models of the wooden models using tags. This allows access to a further sharing environment where it is possible to view and explore 3D models (Figure 6).

Figure 5. Virtual tour of the Department. View of the *Sala Oreglia* where the wooden models of the vaults of the Curioni collection are kept.

A second phase of the project involves the creation of an interactive environment within the Unity 3D Game Engine workspace. Through the realization of a targeted knowledge path, the user will be able to explore and interact with models, and answer real questions that will test their knowledge, similar to a video game. The development of research within the Unity environment aims to construct an immersive First-Person Shooter (FPS) game. This involves creating scenes where objects or 3D models can be inserted, enhanced with textures, lighting, and graphics (both static and dynamic, through animations), and then rendering the entire scene (Ritharson et al., 2022) to create a game environment that is as realistic as possible.

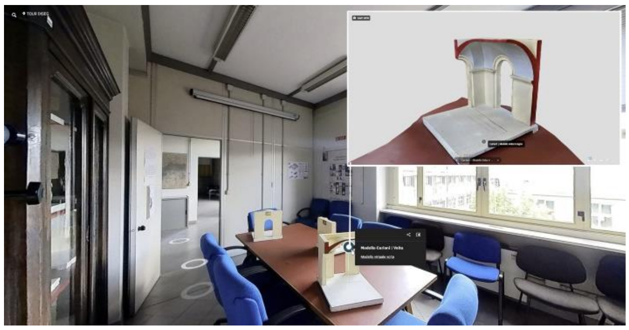

Figure 6. Virtual tour of the Department: tagging wooden models and displaying the virtual model within the Sketchfab sharing environment.

Figure 7. Virtual tour of the *Sala delle Colonne* at the *Castello del Valentino*, Turin, Italy.

This methodology can be applied in two settings: first, to recreate the historical spaces that housed the Curioni collection during the years when the Curioni Model Workshop was set up in the *Sala delle Colonne* of the *Castello del Valentino* (Figure 7); and second, to create a customizable virtual environment, adaptable to the storytelling needs of educational and knowledge activities (Figure 8).

In both cases, placing the models within the virtual environment and allowing the player to move freely and interact with the virtual models, by questioning them and responding to questions or problems, enables the user to actively participate in the experience and fully customize it to their needs.

Figure 8. Some images of the models included in the virtual museum realised in Unity.

4. Discussion

The research highlighted three main components: 1) cognitive (information system design and data and information flow); 2) instrumental (hardware); 3) procedural (hardware, software, and people, i.e. conservators, scholars, and wide users).
From the outset, it is evident that an understanding of the limitations and potential of the single models and of the museum consultation environments created is of paramount importance. Three different cognitive stages can be distinguished.

Phase 01: Information Model: this phase concerns the realisation of the geometric and informative model of the historical asset through digital acquisition and consultation of archive sources. It entails the creation of the exhibition with shared parameters and thematization.
Artefact sharing paths can be:

- sharing of data and metadata with other users by sharing the elaboration in its native environment and opening of the model directly within the creation software. It is possible to view the geometric digital twin of the wooden model, as well as shared parameters and related sources.
- the model can be shared using desktop viewers, which provide a simple visualisation of the geometries of the asset and visualisation of the thematizations created in the geometric and information modelling environment;
- the model may be made public and navigable in its forms and it may also be exported in interoperable formats and imported into 3D web viewers, where it is possible to manually associate notes, images and sources to the different geometries or parts of the model.
- finally, the model may be made public by sharing it on web platforms, where users can interrogate the model and view the associated sources and data.

Phase 02 | Point Cloud Model: generation of the point cloud of the asset with digital surveying technologies, possibility to interrogate, modify and visualise the point cloud in different environments, with heterogeneous objectives and users.
Surface model sharing paths can be:

- sharing the cloud with other users by sharing the model obtained from the images or smart LiDAR acquisition in its native environment: opening the model directly in the creation software, possibility of interrogating the model, reading its geometries and elementary characteristics of the artefact. Possibility of visualising the source images that make up the point cloud;
- model sharing and visualisation could be declined in:
    - information model environment: import the point cloud into the working environment and implement the initial model with information and data derived directly from the point cloud;
    - ability to visualise the model with a higher level of detail than the previously processed and ability to visualise shared parameters and input sources;
    - point cloud viewer: visualisation of the geometries, with the possibility to query geometric data;

Phase 03 | Information System: if the information model is defined by source-based geometric modelling or point cloud acquisition, this aspect of the virtual museum can be divided into other subsystems:

- a consultation environment, which is the digital twin of the real host site and the hosted models (Figures 1-2 and 4-6);
- a hypothetical reconstruction of places that no longer exist or are no longer equipped to host the collection that is spreaded in different places (Figure 7), in order to recreate the original historical space;
- an ideal virtual consultation environment (Figure 8), more suited to a specific type of metaverse that does not reproduce reality, except for the digitised wooden models of the collection;
- an ideal or a realistic space that collects heritage from different repertories in different real places in order to create a fil rouge through specific topics all over the collections spreaded in different cities.

The above considerations, some of which are of a methodological nature, others of an operational and descriptive nature, bring to the fore a question which is considered fundamental, and which comes to the fore again when it comes to transmitting knowledge of technical heritages through the various forms of communication which are disseminated and accessible to heterogeneous audiences. The selection of effective, punctual and rigorous elements, without the risk of omitting interesting or fundamental elements, can inevitably lead away from the original languages of elaboration. For this reason, the digital reproduction of the historical collection, capillary and curated, could represent an independent way of sharing, but in constant dialogue with the critical synthesis carried out and recorded in parallel within the information system.

Texts, formulae, diagrams, tables, drawings, plastic models are in a complementary relationship with each other; in different forms they often represent the same content and are mutually enriched by the direct and material reading of the informative objects, with clues that cannot be fully restored by digital recording.

From what has been developed, it can be deduced that in order to obtain a model that represents the model in all its parts as comprehensively as possible, and for this to be shared by as many users as possible, a clear workflow must be established that defines all the steps for acquiring, modelling and sharing the data and information that define and characterise the heritage.

This applied methodology for structuring parametric and semantic objects of one polytechnic collection, and more generally the explicit use of the semantic web to correlate models and archival sources, needs now to be proven with scholars and the curious at work in consultation and data enrichment.

5. Conclusions

This presented network transcends the boundaries of isolated disciplinary fields, uniting different skills of interpretation and analysis. Virtual collections and ideal museums offer several advantages over traditional patterns of knowledge, including accessibility to a global audience and enhanced interactivity through digital technologies such as 3D scanning, information modelling, semanticisation of point clouds set, virtual, augmented and mixed reality (AR).

The research assumed rapid and low-cost (economic, time and employed human resources) procedures for surveying heritages in their geometric component at different scales of acquisition (building spaces and wooden models), to which, in special open and accessible environments, data and documents can be associated to allow different knowledge filters and different types of interaction.

Future development will focus on the interdisciplinary connections between the Science of Drawing and the Construction and Structural Design Sciences to enhance their epistemological understanding and uses of academic heritage.
As we have seen, the project to enhance the heritage preserved in the archives takes these aspects of care and sensitivity into account, going beyond certain experiences and integrating them into a policy which, at university level, includes the dynamics of the individual departments. The dissemination project, which is constantly being refined, must respect the principle of preservation and increase direct access to documents: time for an experimentation that is no longer an ideal way forward.

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Credits

The research product is the result of a collaborative effort between the Authors. However, the authors present the research and its results in the following order: 1. Introduction, G. Garzino; 2. Museums in the digital domain: a state of the art, 2.1. Science of representation and virtual museums, M. Pavignano; 3. Methodology, M. Vozzola; 4. Discussion, 5. Conclusions, M. M. Bocconcino.

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