GIOVANNI CURIONI'S DIGITAL MUSEUM (1/2): COMPARATIVE SURVEY TECHNIQUES FOR THE DEFINITION OF A 3D DATA COLLECTION PROCEDURE WITH LOW-COST SYSTEMS

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KEY WORDS: Workflow, Image Based Modelling, Representation Techniques, Lidar, Photogrammetric Techniques, 3D Reproduction, Digital Model, Low Cost.

ABSTRACT:

The potential of Virtual Heritage, with particular attention to the field of knowledge dissemination, not only in the educational and scientific field, of museum collections, which are very often not accessible, have long been at the centre of the digitisation policies of major national and international institutions. Within this framework, the proposed research is part of a broader research, involving scientific figures from different disciplinary fields for the definition of a workflow for the 3D acquisition, digitisation and creation of a virtual model of miniatures of architectural artefacts kept at the Polytechnic of Turin. The paper describes part of the experimentation conducted for the creation of 3D surveys carried out using different tools, such as a portable LIDAR, Mantis F6, a low cost LIDAR, iPhone 13 Pro, and a digital camera, Nikon Z5, evaluating their performance not only from a metric point of view, but also from a methodological point of view and the subsequent sharing of models in accessible digital environments. The conducted study therefore initiates a process of memory digitisation in order to create a digital platform in which to insert, in an organised and digitised manner, models, data, historical morphological information, material, documentary, etc., in order to make interaction with the virtual reconstructions possible, promoting a new accessibility, all this to test, standardise and define a possible working protocol for massive low-cost 3D artefacts acquisition.

1. INTRODUCTION

The 'Giovanni Curioni' collection of wooden models hosted by the Department of Structural, Building and Geotechnical Engineering of the Polytechnic University of Turin (DISEG) bears witness to the commitment to the educational field of construction science made by Professor Curioni in support of the teaching content published in his volumes *L'arte di fabbricare. Costruzioni civili, stradali e idrauliche* (*The Art of Building. Civil, Road and Hydraulic Constructions*) published in 1870's. The didactic function of models is now being rediscovered as part of a project of valorisation and vivification conducted by a composite research group[1]; specific skills and disciplines converge in it: in the field of construction science Professor Mauro Borri Brunetto; for the responsibility of the cultural and scientific heritage of the University the architect Margherita Bongiovanni and doctor Francesca Gervasio; on the sciences of representation and information modelling the Authors of the contribution; on geomatic and measurement skills the author Professor Marco Piras and Paolo Dabove with the engineer Nives Grasso; as support to acquisitions and elaborations the DISEG technician Pierluigi Guarrera and the student building and civil engineers Tommaso Verdier and Muhammad Daud. The articulation of the research group testifies the intra- and multi-disciplinary interest of the collection to which it is intended to associate an intangible dimension related to the informational heritage of educational character that it is possible to update, consolidate and continue to transfer to future generations.

With the occasion of the CIPA 2023 conference, we wanted to propose two foundational aspects of the work being conducted[2], presented individually in two contributions, of which this first one represents the methodological setting and the approach to the subject from a point of view of the survey system and processing procedures, also with reference to material and digital products. The second contribution (Giovanni Curioni's digital museum: possible strategies for a data management plan) returns in a complementary way to this first one the relevant elements for data management and its organisation within information containers for knowledge.

The aspects of interest that will be highlighted in this contribution reside mainly in the nature of the tools employed, critically compared, and in the ways through which parametric digital models operating within integrated information systems are arrived at.

[1] Attribution note: all authors contributed equally to the research. In writing paper, MMB and MPi are responsible for paragraph 1; MPV for paragraphs: 2, 5 and 7; MPV e LG for paragraph 6; MPa for paragraph 3 and 4.

[2] The research started with some works published from 2018 (Novello and Bocconcino, 2018a; Novello and Bocconcino 2018b; Santagati et al., 2018).

https://doi.org/10.5194/isprs-archives-XLVIII-M-2-2023-235-2023

2. CURRENT DEVELOPMENTS AND TECHNOLOGIES

3D digital survey and modelling applied to models belonging to museum collections or archaeological artefacts represent a field of research in continuous development, which bases its principles on the communication, sharing and dissemination of knowledge of objects that are not always accessible to users. The use of surveying and 3D representation systems, through the creation of navigable, measurable, and interrogable virtual models, has established itself in recent years as a response to the emerging need to disseminate and share the historical memory of artefacts that can be used both for educational purposes and for cultural dissemination, aimed at users with different levels of knowledge and objectives for using the model. There are, in fact, numerous national and international testimonies, which have seen the development of research based on 3D digital survey, aimed at the creation of real digital museums - not dealing here with the subject of 3D building surveying. The first applications on the use of images for the construction and realisation of 3D models led to the development of - experimental - Visual Structure from Motion techniques (Szeliski and Kang, 1993) able to return complex 3D artefacts (Remondino et al., 2005; Remondino et al., 2014) that can be considered digital copies of the surveyed elements, usable for different purposes. However, despite the fact that these issues have been part of national and international research for years, there is still a heated debate on the most appropriate survey methodology to be used and applied depending on the type of artefact to be surveyed and depending on the intended use of the digital model: many authors prefer an integrated data acquisition methodology (Collins et al, 2019; Parrinello et al., 2022; Kesil et al., 2023), always relying on the use of photogrammetric acquisition tools that avoid direct contact with the object, in order to limit the introduction of potential causes of degradation on the external surface of artefacts. Today there is no protocol for the acquisition of artefacts, both because of the vastness of the instruments available, but above all because of the characteristics of the objects to be surveyed: there is a vast literature on these topics, which allows us to hypothesise a general pipeline, aimed at obtaining geometrically correct digital models (Guidi et al., 2010; Pietroni et al., 2014) for the purposes of dissemination and knowledge defined at the beginning of the survey phases. In recent years, surveying techniques have further changed thanks to developments in the instrumental field and implementations of digital data management, using low-cost and easy-to-use surveying tools, such as the Lidar cameras built into the latest generation of Iphones and Ipads (Fiorini, 2021; Russo et al., 2019; Spreafico et al., 2019). Within this panorama, new experiments are emerging for the evaluation and subsequent validation of fast data acquisition methodologies, aimed at using 3D surveying techniques and tools, low cost or not, evaluated as suitable according to the type of artefact to be surveyed, but above all suitable for the type of output desired and the feasibility time of the survey campaign. It must not be forgotten, however, that when choosing the most suitable surveying instrument and technique, particular attention must be paid to the size of the artefact, its accessibility, the type/colour/opacity of the material, the environment in which it is placed and the light, all parameters that can influence the acquisition methods and the expected results. In recent years,well-defined methodologies with increasingly accessible 3D systems have made it possible to plan massive 3D acquisition campaigns of entire museum collections, building accurate databases of digital twins (Guidi et al., 2015). A brief overview of the latest national and international research can be referred to the Collections of the Egyptian Museum in Turin (Mezzino et al., 2022; Lo Turco et al, 2019) or to the narration of archaeological excavations through the realisation of a virtual environment where digital archives of historical datasets and artefacts are narrated, which within the digital platform combines and relates survey data, modelling and images, thus offering the possibility for users to customise their own knowledge path as needed (Meyer et al. 2007; Gershon, 2021; Parrinello et al., 2022).

3. ACADEMIC SCIENTIFIC COLLECTIONS AND MUSEUM, TOWARDS VIRTUAL DISSEMINATION

Academic institutions, especially those that were already active during the XIX century, usually hold tangible and intangible heritage related to their history. In the last couple of decades, the scientific community has become aware of the importance of such heritage since it might represent an important piece of the scientific history of research and didactic within such institutions, as well as piece of "relational materiality" between the public and the university (Maurstad, 2012, pp. 175-176) when exposed to public within academic museums. In the Italian context we cite the examples of the Museo Universitario di Chieti (Università degli Studi di Chieti-Pescara "G. d'Annunzio", Chieti, Italy) (www.museo.unich.it) - with its collections related to natural sciences and history of sciences - and the Museo di Antropologia Criminale Cesare Lombroso (Università degli Studi di Torino, Turin, Italy) (www.museolombroso.unito.it/) with its collections of artifacts related to anthropological criminology. From the point of view of the discipline of drawing and representation, we can recall the case of the Collezioni Botaniche del Museo di Storia Naturale dell'Università di Firenze and its project "Beccari in 3D", which deals with the design of a digital and online section of the academic museum (Puma et al., 2022). In a wider panorama we cite the Museum der Göttinger Chemie (Georg-August-Universität Göttingen, Göttingen, Germany) - and its collection of history of chemistry - (www.museum.chemie.uni-goettingen.de) or the MIT Museum (Massachusetts Institute of Technology, Chambridge, MA, USA) and its "more than one million objects" depicting MIT interests from 1861 (mitmuseum.mit.edu).

Many universities are now also providing digital museums. In this sense, the evolution in terms of dissemination and public engagement is going towards a new complexity. We may find a paradigm of this evolution in the physical and digital museum of the Eberhard-Karls-Universität Tübingen (Tübingen, Germany) (www.unimuseum.uni-tuebingen.de/en/).

The digital one provides: 360° digital exhibitions (3D navigable models); entire collections catalogued online (each piece of heritage has a single file with images and textual data) and will host a 3D-museum (Fig. 1).

These examples provide a limited but interesting view over the new modalities used by academic institutions to create new representations of their history and cultural values. In this sense, we can observe how new types of public engagement (being digital collections, 3D virtual tours, digital museums) grow inside the statutes of representation, thus pushing the use of digital data towards its critical interpretation, as best shown by the Museo della rappresentazione (Museum of representation) of the Università degli Studi di Catania (Catania, Italy) (Galizia et al., 2019).

Another interesting example is the Museo virtual: Luis Quintanilla of the Universidad de Cantabria (Spain) designed for preserving the historic memory of the institution with the support of 360° virtual tours enriched with seven virtual rooms (García Gutiérrez and Ruiz López, 2021).

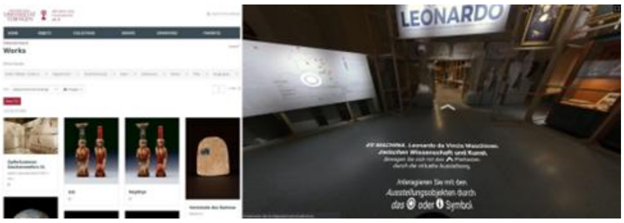

Figure 1. Digital museum and collections of the Eberhard-Karls-Universität Tübingen.

4. COLLECTIONS OF TANGIBLE ARTEFACTS AT THE POLITECNICO DI TORINO

The Politecnico di Torino, formerly Regia Scuola di Applicazione per gli Ingegneri (Royal School of Applied Sciences for Engineers) founded in 1859, possesses a rich material heritage.

Set	n° of models	Example
Retaining walls	13	
Ground works	20	
Bridges and frameworks	36	
Railways	14	
Tunnels and frameworks	18	
Building machines	8	
Hydraulic constructions	7	
Vaults	25	
Total	**141**	

Table 1. PoliTo material heritage: Curioni's models. Figures courtesy of Politecnico di Torino.

This is divided in two main areas: archival collections and scientific collections (collezionistoriche.polito.it). The latter contain many sets of physical models (or tangible artefacts) of various kinds, many of which are preserved in the academic Departments (Bongiovanni and Angelini, 2019). These collections were established - back in the day - to provide technical support to research and teaching; thus, they deal with artefacts of civil and mechanical engineering, mineralogy, topography, mathematics and more.

Those collections represent tangible memories of the 160 and more years of the academic history of our university, and currently they are subjected to a wide program of cataloguing, aimed at renovating internal archives and at online dissemination. Our research focuses on the collection of wooden models conceived and designed by Giovanni Curioni as tools «at the service of building science» (Faraggiana and Sarri Perino, 1989, p. 7). He was professor of civil constructions at the Regia Scuola from 1866 until his death (Sassi Perino, 1989, pp. 15-17) and was recognized as a highly experienced scientist and professional, as well as a high-level teacher. The main purpose of Curioni's models was to connect theoretical knowledge taught in the courses of the Regia Scuola and the professional practice. In this sense, Curioni's models helped in defining the core of our 'polytechnic culture', and Curioni did his utmost to establish the Laboratory of materials experimentation, founded in 1879 (Sassi Perino, 1989, pp. 18-19). He then conceived and produced the collection of 141 models for building science between the second half of the 1860s and 1887.

Today, this collection can be divided into sections referred to: 13 retaining walls, 20 groundworks, 36 bridges and frameworks, 14 railways, 18 tunnels and frameworks, 8 building machines, 7 hydraulic constructions, and 25 vaulted structures (see Tab. 1). The artisan Giuseppe Blotto built these artefacts in the 1870s (Faraggiana, 1989, pp. 92-94) on the base of Curioni's representations in orthographic projection published in the treatise about the Arte del Fabbricare (building art) (1866). There is an almost perfect correspondence between Curioni's drawings and Blotto's models, thus being their 'tangible' declinations (Cumino et al., 2022, p. 93). Our project aims at defining new digital representations of Curioni's models to be included in the - already cited - on-line historical collections of our Politecnico.

5. METHODOLOGY

3D models represent accurate, scaled digital replicas of real objects that can provide relevant information on morphology, volume, appearance, state of preservation and material (Berto and Salemi, 2019). But the key aspect of 3D virtual reproduction lies in the possibility of displaying the models, as virtual content, in virtual museums. The study of digital narrative modes becomes a test bed for scholars in the field of survey and representation in order to respond to the emerging challenges posed by European and international goals of inclusiveness and educational quality based increasingly on the possibility of remotely delivering innovative didactics.

It is within this context that our research moves, which aims to test and standardise a procedure for the realisation of virtual models, using different sources as a database, to prepare a virtual museum that can be consulted primarily by students to deepen their knowledge in the field of construction techniques of certain architectural apparatuses, comparing and contrasting what is described in the texts of engineer Curioni and what is realised in the physical model. To achieve this objective, the same virtual model was created using different surveying and modelling techniques. To understand which acquisition and modelling methods were most suitable for the reaction of the virtual model, in an initial experimental phase some models from the Curioni collection were surveyed using different data acquisition methods, which led to the creation of different virtual models:

a. range-based survey, obtained through the use of two different instruments: the structured light laser scanner (Scanner Mantis F6) and the low-cost Lidar scanner, supplied with the Iphone 13 Pro, which allowed us to create a virtual model from a point cloud, in the first case through export to suitable modelling environments, in the second case directly within dedicated apps;
b. image-based survey, carried out using a Nikon Z5 digital camera with calibrated 18-55 mm lenses, in order to obtain a point cloud from which to create the virtual model in a modelling environment;
c. direct survey of the physical model, obtained by using traditional tools, from which it was possible to deduce all the geometric data of the elements and create the parametric virtual model in a BIM environment.
d. reading the drawings and engineer Curioni's manual, from which it was possible to deduce the information and geometric data to create the virtual parametric model in the BIM environment.

The comparison of the different surveying techniques and modelling phases analysed the processes carried out and the models obtained, to assess the best solution in terms of tools (cost/time/operator knowledge), collected data (quantity/quality/acquisition times/interoperability) and optimal solution (model quality/metadata/processing times/interoperability/sharing), to speed up the entire acquisition and/or virtual modelling flow, and to pursue the objectives of sharing the model within a virtual platform using a standard data acquisition procedure (Tab. 2).
Within the platform, the graphic content of different origins, and data related to the asset of a graphic, photographic and alphanumeric nature may converge, but above all the metadata related to the model must be archived; it will be fundamental not to lose sight of the dualism between the scale of representation, and therefore its visualisation, and the content of the virtual model.
Our idea is therefore to create a procedure that can be easily replicated by professionals who are not necessarily trained in the more technical aspects (Li et al., 2016), creating a digitisation path that connects drawings and models (Parrinello et al., 2022) in order to define a language that can make information and alphanumeric data explicit according to the end user.
The project aims to record in 3D the complete morphology of each model to make a virtual copy of it, focusing not only on the acquisition process, but also on the most efficient survey methods and techniques, not forgetting to evaluate the quality of the output obtained. Workflows based on the acquisition of data for virtual modelling using "traditional" and "low-cost" devices will therefore be compared, focusing on the narrative of the procedures and enhancing the tools of drawing and representation. The multi-level information associated with the model can be communicated to different users via the sharing platform.
In this article, we will mainly deal with the realisation of virtual models based on the acquisition of data obtained with the portable LIDAR, Mantis F6, low cost Lidar, iPhone 13 Pro, and Nikon Z5 camera. It is evident, as witnessed by numerous scientific publications (Allegra et al., 2017), that the resolution of the final geometry acquired with the different survey tools and representation techniques depends on several factors. In particular, the quality of the acquired data varies depending on the complexity of the geometry, the material - in particular the colours of the different elements - and the intensity of the ambient light in which the object is located during the survey phases.
The focus of this work is to create a robust procedure for the acquisition of 3D data and its post-processing in order to obtain the best digital restitution, with the possibility of creating a 3D reproduction that can be interrogated to acquire documentary information. To assess the effectiveness of the data collection steps, several tests were conducted to investigate:

a. the ease of use of the tools for an inexperienced operator;
b. the modalities and timing of the post-production phase of the data collected with the different instruments, evaluating the different processing environments, to create a workflow that is lean and fast, but above all easily replicable;
c. the formats that best allow for accurate data transmission;
d. the best environment for publishing the 3D model.

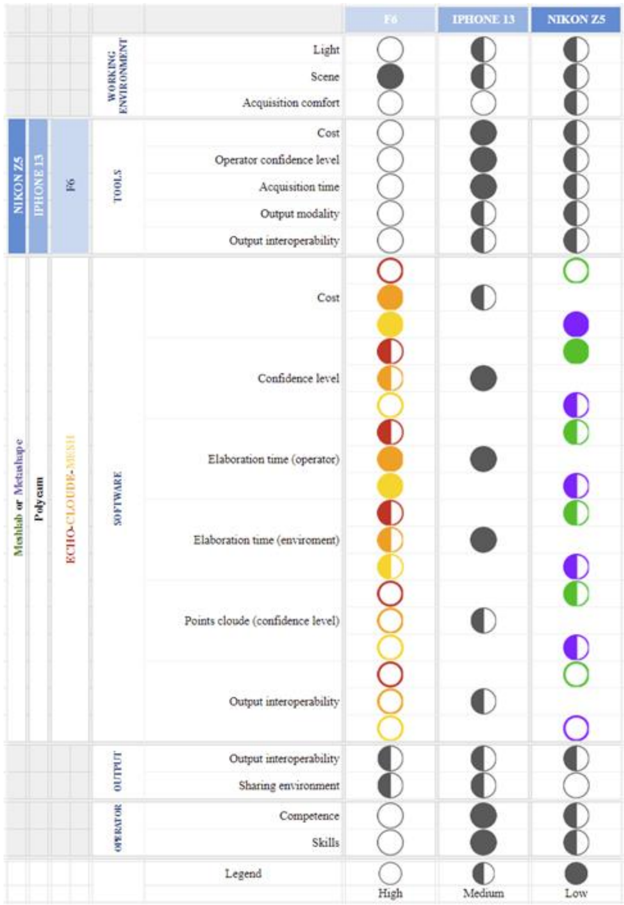

Table 2. Workflow evaluation: efficacy of survey tools and managing software.

6. APPLICATION

In the following paragraphs we will deal specifically with the different workflows according to the acquisition tool used:

- LIDAR Mantis F6
- Nikon Z5
- iPhone 13 Pro.

LIDAR Mantis F6

The LIDAR (Light Detection and Ranging or Laser Imaging Detection and Ranging) technique is undoubtedly the most effective technique in terms of quality and accuracy of point cloud acquisition, as is amply demonstrated by the numerous bibliographies available (Lachat et al., 2017). In the case study, we opted for the use of a handheld lidar instrument, F6 Short Range, supplied together with the software, ECHO Software (Patrucco et al., 2019). Acquisition requires the possibility of a good manoeuvring space that is free of obstructions and that allows for fluidity of movement of the operator. In addition, the management of light is particularly important, as this affects the quality of the point clouds, so a white calibration is required every time a new survey session is started, as without such a calibration we run into trivial and gross acquisition errors regarding the colour of the model.

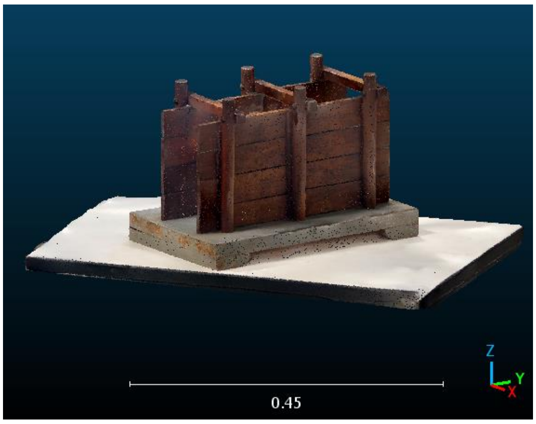

Figure 2. The digitization and virtual reconstruction of Curioni Model: the point cloud acquired by laser scanner.

A further precaution to be taken is the availability of ample storage memory by the device used in combo with the LIDAR instrument. The model was prepared with markers that were used in the postprocessing phase for the various alignment operations of the different sockets and filters as the best practice in the field requires. It was seen how the entire acquisition and post-processing procedure requires the use of a trained operator. It was noted how inexperience leads to having sparsely populated frames (set of clouds acquired during a single acquisition phase, Fig. 3). The best condition is a few very dense frames. This inconvenience can occur for several reasons, including the excessive or insufficient distance of the instrument from the model, the change of distance during acquisition and finally to excessively abrupt movements of the operator.

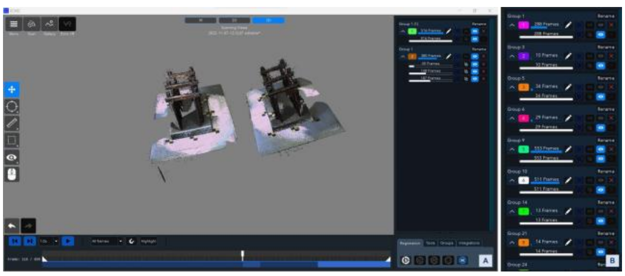

Figure 3. Comparison of two different acquisition phases of the same model with the Mantis F6 LIDAR, but with different results: a. survey carried out with only 2 survey sessions but obtaining a very dense point cloud; b. survey carried out with 21 survey sessions but obtaining a not very dense point cloud.

Nikon Z5
As with LIDAR the environment condition is very important. The brightness of the environment even more so plays a fundamental role in the correct representation of the colour of the model. A correct acquisition in this part makes it possible to avoid post-processing resources and the time required by them.
Today, semi-professional reflex cameras allow good data acquisition as long as certain precautions are observed (paste summary table). The acquisition was done by taking several photographs of the same object from different heights and angles in such a way as to cover the entire surface to be surveyed and to have a correct overlap layer. In this specific case we use software to elaborate the photo. Metashape (Vuković et al., 2022) is certainly the most titled, which has proved to have all the requirements needed to manage the acquisition and subsequent production of the digital model.
The user-friendly interface certainly helps even the least experienced operator to learn the correct workflow in a short time. However, the cost is high. A possible open-source alternative that we wanted to investigate, which would however require a minimum training period for the operator, is Meshroom software, which allows the analysis and post-processing part. Acquisition by photogrammetry is suitable for large, medium, and medium-small models. It is unsuitable as it is unable to capture fine detail of small models. The cost of the camera is certainly lower than that of the Lidar and in some cases even of phones, such as iPhones or the like. A negative influence is the purchase of the metashape software, which should be evaluated according to the skills of the operators and the models to be digitised by the organisation.

iPhone 13 pro
The procedure with the iPhone proved to be the quickest and easiest to use, although the accuracy of the model acquisition is minor. In this specific case, the potential of the Polycam app was exploited, making it possible to obtain a finished product that can be exported in various formats. Unlike the previous ones, the acquisition environment does not require any special conditions and the operator's familiarity or unfamiliarity with the procedure is practically eliminated. In fact, even if the model has not been acquired correctly, the application used allows the dataset to be integrated in the second time. Moreover, the result and the possible imperfections or shortcomings of the model are immediately visible. However, its application is interesting for all those areas of digitisation and game making. Surely the main advantage is the ease of use and the possibility of immediately having a dataset that can be used in different formats and published on different platforms.

Post-processing and data comparison
The post-processing and comparison procedures (Fig. 4) of the results were carried out using the open-source software Cloude Compare, which allows various operations to be performed on the point clouds acquired. It should be noted that the joining operations between the different frames acquired through the LIDAR was carried out directly through the software provided by the manufacturer, ECHO software.

Tool	Points cloude format	Initial Points	Points after post-processing	Mesh
Mantis F6 	.ply	25656017	15797683	
Nikon Z5 	.las	57081559	3898312	
Iphone 13 Pro 	.laz	1122840	831647	

Figure 4. Main data of instruments and acquisition set-up.

The point clouds acquired were first manually cleaned of those parts that were not relevant for the purpose of the work, thus carrying out a coarse cleaning of the point cloud, which did, however, make it possible to obtain a more easily workable product.
Subsequently, the clouds were processed through three different types of filters to obtain the best possible result in terms of both density and quality of the cloud. The filters used are:

- Remove duplicate points;
- SOR Filter - Statistical Outlier Removal Filter;
- Noise Filter - Noise reduction filter.

Which used together allow the removal of duplicate points, the reduction of outlier points and noise reduction.
After the filtering operation, it was possible to generate the meshes from the three different point clouds.
In particular, this was done differently depending on the origin of the point clouds. The point cloud from the lidar survey was processed through the open-source software, Meshlab. While the Metashape software and the Polycam app made it possible to obtain the mesh immediately without further steps through additional software.

Figure 5. Example of visualisation of two digital models from the Curioni collection within the Sketchfab sharing environment, where information can be obtained by indexing the linked sources.

Model sharing

The final step of the work has been the correct model sharing strategy, both platform-side and format-side. This investigation was conducted following the most up-to-date FAIRS principles (Hodson et al., 2018) and the Parthenos lines guides (available at https://www.parthenos-project.eu). The stl. format was identified as the most suitable for public sharing since it contains all the geometric and chromatic data within it and allows a 3D print of the model itself. The publication environment identified as the Skechfab sharing platform (insert article) allows for simple model sharing and at the same time guarantees the possibility of updating the data and its constant management. Platforms such as Skechfab allow the model to be enriched with additional information, thus complementing the purely material and geometric information. Allowing a finished product enriched with related and interwoven information. The work proceeds with the creation of a virtual museum through the Unreal Engine software that will allow the integration of VR and will make the experience similar to that of a game as quests can be added to the model with which the students of the polytechnic of Turin can interact, thus applying the theoretical concepts learned in class from the comfort of their own homes (Fig. 5).

7. DISCUSSION, CONCLUSION AND FUTURE DEVELOPMENTS

The research presented aims to define a methodology for the creation of digital models of archival or museum collections stored in repositories and not accessible to the public, constituting a workflow capable of virtually reproducing spaces (the container, i.e., the museum) and objects (the content, i.e., the collections) (Lo Turco and Spallone, 2019).
The activities carried out consisted of several phases: reading historical/archival documentation, direct and indirect survey of the collections, discretisation of the acquired models, and finally sharing the virtual models in different 'container' environments. Since digital models are intended to be used as a support to heritage knowledge and dissemination activities, it is essential to understand the end user who will use it, in order to identify the most suitable data acquisition/processing path depending on the intended use of the model. In the first phase, the research therefore aimed to test the use of different surveying instruments and to assess their performance from a metrological point of view, applying this methodology to the Curioni Collection, preserved at the Polytechnic of Turin.
Focusing on the phase of the acquisition of the geometric data of the models, the small size of the models and their transportability allowed different acquisition set-ups to be configured, obtaining comparable results between different acquisition methodologies: structured light laser scanner, low-cost Lidar scanner and digital camera. From an instrumental point of view, we can conclude that the use:

1. light laser scanner proved to be very accurate for the type of models to be developed, but nevertheless due to the geometry of some of these, it is difficult to handle and complex to adapt to the morphology of the model. Although the acquisition phase turns out to be fast, the data processing and post-production phase is quite lengthy;
2. Lidar as a 3D acquisition tool for simple models (with elements of minimum geometric dimensions of 1 mm) was sufficient. In this case, both the acquisition phase and the data processing phase are fast;
3. photogrammetry presents greater flexibility in terms of the context of use, the geometry of the model to be surveyed, but places the constraint of controlled and uniform light over the entire surface of the model in order to obtain sharp and optimally usable images. Furthermore, unlike the two previous methods, it does not allow results to be verified in real time, but only during processing (Russo, 2022).

From the evidence above, and from an analysis of the various survey/management/environmental boundary factors, but above all focusing on the objectives set, the 3D survey with lidar on the iPhone 13 Pro was more than satisfactory for the scale of representation and the level of detail required as the result of the digital twin of the original wooden model.
The above shows that to understand the optimal workflow for the acquisition of models, it is necessary to understand the desired representational quality of the virtual model: different digital models, obtained with different data acquisition and modelling techniques, respond to different narrative and dissemination objectives, addressing users from different

knowledge domains and belonging to different processing/sharing environments.
The next step after the acquisition of the models was to understand which possible sharing environment could meet the knowledge dissemination needs associated with the virtual model archive generated by the subsequent data acquisition and processing.
The last part of the research was devoted, and is still being devoted, to the evaluation and testing of sharing and dissemination environments. Precisely in recent years, due to the recent global pandemic, we have witnessed a new acceleration in the dissemination of study content and interactive applications related to the virtual reconstruction of artefacts (Vozzola, 2021): we have therefore devoted ourselves to analysing the state of the art of the best-known online sharing platforms, in order to qualitatively assess their properties. Among the sharing environments analysed, we studied and tested possible applications in Google Arts and Culture, CyArk, 3dHOP, Sketchfab and Game Engines (Statham, 2019; Champion, 2020). From the preliminary investigation, it was decided to proceed along parallel paths: on the one hand, testing the sharing of models within the Sketchfab environment, which allows for a quick and easy sharing of the model, but at the same time guarantees the possibility of updating the data linked to it, and on the other hand, setting up a real ad hoc 'museum' environment, elaborated in Unity Engine, where it will be possible to view the models and through the use of augmented reality create real gaming (Fig. 6).

Figure 6. Example of visualisation in Unity Engine (version 1).

The next steps of the research will be aimed firstly at the automation of the 3D data acquisition procedure, to minimise possible errors, whether due to the operator, more or less specialised, or simply due to human error, but above all aimed at optimising the costs and times of the procedure. Secondly, we will focus on the completion of the realisation of the sharing platform, which will relate drawings and models, for the definition of a language capable of explicating multiple reading and narrative paths adaptable to the type of user, but above all, as already developed in Unity Engine, allowing students to practise "playing" with the digital twins of the Curioni models, through applications and exercises developed ad hoc.

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