VR, AR and Tactile Replicas for Accessible Museums. The Museum of Oriental Art in Turin

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Abstract

This work is part of the agreement stipulated between the Department of Architecture and Design of the Politecnico di Torino and the Fondazione Torino Musei for the enhancement of the cultural heritage of the Museum of Oriental Art (MAO). The agreement aims at the realization of accessible exhibition paths including multi-sensorial experiences *in situ* (tactile paths and AR experiences) and online (VR proposals) in the MAO.
Specifically, six stages of this path have been identified, including the museum's entrance hall and five artworks (one for each geographical area of the collection) which are the subject of the survey and restitution process. This involves thesis students of the Design and Visual Communication course of Politecnico di Torino for the development of prototype apps on the selected works and one of the authors for digital fabricated models and replica.

Keywords
VR, AR, tactile models, museums, inclusion.

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Introduction

In the last few years, the development of three-dimensional digital acquisition technologies has led to interesting results in the field of cultural heritage protection and valorization. In the museum field, on the one hand, there has been the creation of digital archives and, therefore, the delocalization of collections, and on the other hand, a greater attention to accessibility in presence. AR, among other technologies, has become a tool for discovery-based learning that enhances the information accessed by visitors within galleries, interacting with objects in the real world [Ding 2017, pp. 1-15].
The goal is to increase visitor involvement, making the museum experience more educationally incisive and more inclusive, in a "Design for All" perspective [Ronco 2021, pp. 49-61], moving from a standardized end-user vision to a holistic one (real end-user) [Rossi & Barcarolo 2018, pp. 257-269].

Multilevel Experiences in the Museum Field

The models obtained with different digital acquisition techniques allow new ways of content fruition. Both virtual and physical outputs aim to increase the inclusiveness of collections, meeting the different needs of users related to age, physical, sensory, cognitive, cultural and experiential factors.
These technologies, digital modelling and fabrication permit the automation of processes and the reproduction of the object in different formats. The diffusion of VR and AR devices has allowed to define new ways of visiting with an increasing level of involvement of visitors.
VR technologies enable visitors to live an experience very similar to the real one, but above all to receive additional content, such as the spatio-temporal contextualization [Walczak 2006, pp. 93-95]. AR technologies, on the other hand, can change the way the on-site visit is understood [Barry 2012], by adding (side-by-side or overlapping) digital content to the real object.
AR, as the direct tactile experience, offers new opportunities for interaction, including people with sensory and cognitive disabilities. While typically linked to visual experiences, it can include auditory, haptic, and olfactory experiences, expanding the channels of knowledge transmission [Sheehy et al. 2019, pp. 67-85].
These technologies are being used by the most cutting-edge museum institutions internationally as a means of adding new methods of "reading" to more traditional visit paths [Petrelli et al. 2013, pp. 58-63]. Increasingly, multilevel and multisensory experiences are proposed, which contribute to the knowledge of the surrounding reality and to the autonomy of the user, rising respect and social inclusion.
This paper aims to demonstrate some concrete examples of the use of the above technologies and methodologies. In the Italian scholar panorama, Alberto Sdegno has been conducting research on the acquisition, reproduction, and visualization technologies (AR, VR, and digital fabrication for tactile models and replicas) for cultural heritage enhancement for several years. Recently, his research group worked on the physical reproduction of two busts by Franz Xaver Masserschmidt, located at Palazzo Coronini Cronberg [Sdegno et al. 2017, pp. 969-976]. They used the most sophisticated declinations of research tools from three-dimensional scanning, and advanced modeling to 3D printing, taking care to inclusive access mainly to people having reduced visual abilities. The workflow included the 3D survey with a structured light scanner, the reverse modeling, and the 3D printing. They used an FDM (Fused Deposition Modelling) printer, with a PLA (Polylactic acid) white filament, to be painted afterward. This activity represents a benchmark from a procedural point of view for the work subsequently presented.

Accessibility and Inclusiveness of Turin's Museums

Is there a "Turin" model for museum accessibility and inclusiveness?
In the last few decades, museum accessibility has made great strides and Turin is leading the way. The first experiments began in the 1980s.

Research and experimentation are continuous and have been made possible by the alliance between cultural institutions, associations that protect the rights and represent the disabled people, public administrations, private and banking foundations in the area [Rolli 2020, pp. 23-41].
As far as permanent installations are concerned, at the Museo Nazionale del Cinema, the first intervention for accessibility was started in 2006, as part of the project "*Oltre la visione: il museo da toccare, il cinema da ascoltare*".
In June 2007, the first tactile area of Mole Antonelliana was inaugurated proposing a tactile exploration of the architectural spaces that house the museum. A panel with a relief map and Braille writing indicates the position of the exhibition area and the services available on the reception level. At the ground floor is placed the wooden model of the Mole in section (scale 1:100) that allows knowing also through touch the structural characteristics of the building and its historical stratifications [Levi, Rolli 2012, pp. 40-43].
The second stage was the inauguration, in June 2009, of the exhibition room "*L'ottica*". Also in this case, different tools and information supports were provided: interactive exhibits, three-dimensional tactile models, panels with texts and drawings in black and transparent relief.
The other work presented is the one carried out in 2012 at Palazzo Madama on the panoramic tower. In correspondence of each of the eight windows of the tower, a visual-tactile panel was placed with the photographic reproduction of the portion of landscape visible from that position and the selection, through graphics, of buildings and orographic reliefs of interest. On each panel was placed a QR-code and an NFC (Near Field Communication) that allow the use of a video with translation in LIS (Italian Sign Language) and subtitling, which made the texts usable to the deaf.
In 2015 another project – "*Abili per l'arte*" – was carried out in Palazzo Madama, as the response to the challenge of learning not only about relief or three-dimensional objects but also about painting, whose fruition is traditionally limited to the verbal narration. Five paintings made between the Gothic and Renaissance periods were selected and a board was made for each one (Fig. 1). The works can be enjoyed by unsighted people thanks to the relief reproduction of the images and the possibility of activating the audio description.
Another example is the Galleria d'Arte Moderna (GAM) where, in 2021, thanks to the *Fondazione CRT's Esponente* project, it was possible to create some visual-tactile panels of paintings that activate audio-video descriptions in Italian, English and LIS (Italian Sign Language). The panels available to the public are in special containers placed at a usable height along the exhibition path. Through multimedia and multisensory devices, these can communicate in a simple and inclusive way the pictorial work to the widest possible audience, with particular attention to people with sensory difficulties (blind, visually impaired, deaf, hearing impaired).

Fig. 1. Antonello da Messina, Ritratto, d'uomo, tactile panel and the LIS linked video (photo by R. Rolli).

The Museum of Oriental Art: the Case Study

The proposed research aims to build an accessible exhibition that includes tactile models of the architectural spaces and a small part of its collection within the MAO, which together with Palazzo Madama and the GAM, is part of the Fondazione Torino Musei, thus completing its offer.
Currently, the museum does not offer any structured arrangements within the exhibition space to ensure 360° accessibility and at the same time, the services offered are not yet conceived in an inclusive "for all" perspective, despite the will to do so. The educational services of the MAO, which are particularly active, propose activities with visit routes and workshops that are targeted and adaptable to different types of disabilities. Specifically, they propose a tactile path for blind and visually impaired people that develops within the collection of South Asia and Southeast Asia where it is possible to carry out the tactile exploration of selected works, mainly in stone [anonimous 2015].
The work of the research group, coordinated by Roberta Spallone and Marco Vitali of Politecnico di Torino, began in 2019 by the international collaboration for the project "New technologies for the analysis and conservation of architectural heritage", funded by the Ministry of Science, Innovation and the University of Spain. On this occasion, the participation as visiting professor of Concepción López of Universidad Politecnica de Valencia, implemented the research work carried out in recent years [Spallone, Vitali 2017]. The latter, based on brick-vaulted systems in baroque buildings in Piedmont, was thus enriched by data derived from a metric survey campaign with a terrestrial laser scanner (TLS). The atrium, the staircase and the hall of honor of Palazzo Mazzonis, headquarters of the MAO, are among the spaces surveyed.
An ongoing framework agreement between Politecnico di Torino and MAO has also allowed a certain continuity in the collaboration that has led to the development of several degree theses in Design and Visual Communication and the PhD thesis of one of the authors of this paper (F. Ronco).
Multidisciplinarity results as a fundamental element to allow the system to be replicable and scalable [Hervy et al. 2014, pp. 1-4]. The multidisciplinary team sees the involvement of museum conservators, professors, thesis students [1] for the development of prototype apps on the selected works and the arch. Rocco Rolli of Tactile Vision Onlus as a reference for the issues of accessibility and inclusion of the exhibition proposals.
The group, therefore, includes the knowledge of representation, information processing systems, art history, archaeology and museography.

From the Survey to the Museum Experience: the Workflow

The project involves the construction of new narratives inside the MAO through tactile, auditory and visual experiences in AR and VR. Specifically, the work is focused on the survey and restitution of some architectural spaces (entrance hall, monumental staircase and hall of honor) and five works (one for each geographical area of the collection), selected according to the parameters of: maneuverability and inspectionability; illuminability; roughness; perceptibility of details; opacity; chromatic richness.
The project involves the identification of a workflow management model from the digital survey of the object to its 3D virtual restitution used for different purposes: the digital fabrication of tactile replicas/models and the creation of VR and AR experiences, based on the original or on the replica.
The surveys were done with two different techniques: Structure from Motion (SfM) photogrammetry for the works and terrestrial laser scanner (TLS) for the spaces.
The acquired data have been processed with Agisoft Metashape® (in the case of the sculptures) obtaining the mesh model that finally has been exported in .obj for the implementation in Blender® environment.
The virtual model of the entrance hall of Palazzo Mazzonis, on the other hand, was made starting from the scans obtained with the Faro Focus3D. Autodesk 3D ReCap™ Pro software was used to clean and align them. The so-obtained point cloud was finally imported in Autodesk Autocad® and cut with vertical and horizontal planes to obtain the characteristic

sections that allowed the realization of the ideal three-dimensional virtual geometric model in Rhinoceros 6®.
Starting from these inputs, the outputs are multiple: modeling of the missing parts, digital fabrication of them and in general of the tactile models, AR and VR experiences.
The realization of these last took shape thanks to the use of Unity with some additional tools such as Vuforia, Model Target Generator, Google VR and Bolt.
All prototypes are developed for mobile devices, so the user can easily install the application on its smartphone.

AR, VR and Digital Fabrication Between Museum Spaces and Artworks

The sculpture of *Dama di Corte* (Fig. 2) has been chosen to test the technique of virtual restoration, linked only to the chromatic aspect. In fact, its excellent state of preservation allows one to appreciate the original colors but not in their integrity. Therefore, post-production work has been done on the texture of the digital model retrieved from the survey, to obtain colors that are close to the presumed original ones. The AR experience, developed with Unity® software, is activated by framing the work with a smartphone. After the introduction of the functioning of the experience, all the peculiarities of the statue (hairstyle, face and shoes) are highlighted in the various steps. Finally, the user can see the chromatic reconstruction of the same, through its digital copy.
On this artwork the process of digital fabrication through the 3D printer has also been started. At the moment a copy in scale 1:5 is realized, for a purely experimental purpose, to test the perceptibility of the details with the reduction of scale. The object turns out to be about ten centimeters high and could be evaluated as a marketing object. As for the tactile replica, now only a portion (the head) has been fabricated for dimensional reasons of the working plate of the 3D printer In the coming months, the other portions will be realized.
Two other selected works are wooden statues of Japanese origin called *Ni-tennō* (Fig. 3), magnificent examples of the artistic production of the Fujiwara period (898-1185). This is a pair of guardians typically derived from the group of *Shi-tennō*, also known as the protectors of the cardinal points. In this case, the most important work was to contextualize the two statues in the *Kōnjikidō*, or 'Golden Hall', located in the complex of *Chūsonji*, in Iwate prefecture, north of the capital. This small building,reproduces exactly the original appearance of the temples of the period.
The AR experience starts from the recognition of the artworks and is developed in six steps that tell the origin and appearance of the two guardians.
On *Ni-tennō* has also been developed a VR app intended for installation on smartphones, which involves the use of the Google Cardboard visor. The experience offers the possibility of observing the statue inside the temple, evaluated philologically compatible by the then director of the MAO, Marco Guglielminotti Trivel [Tamantini 2020, pp. 52-125].
The last artwork proposed here is the standing Buddha (Fig. 4) from the Gupta period, which was one of the major empires of ancient India, ruled by the dynasty of the same

Fig. 2. Dama di Corte: a) virtual model with original texture (by S. Tamantini); b) virtual model with restored colors (by S. Tamantini); c) 3D printed replica scale 1:5 (by F. Ronco); d) AR experience screenshot (by S. Tamantini).

name between the fourth and sixth centuries AD. The sculpture, in the typical spotted red sandstone of the Gupta school of *Mathurā,* shows the hands and lower limbs broken and an elegant body, enhanced by the large round nimbus that frames the head. The Buddha probably showed the gesture of *abhayamudrā* with his right hand and just held up a hem of his robe with his left hand, according to the canonical iconography of the period. The oval and full face and the high *ushnīsha* on the head are inserted in the center of the large halo – of which only the right portion is preserved – decorated with plant motifs arranged according to concentric frames that follow the central corolla of lotus flowers.
Here the 3D reconstruction of the missing parts was realized, in a perspective of digital archaeology. The reconstructed parts were made to complete the sculpture, but without the application of the texture, so that there is a clear distinction between the original work and the reconstruction. Similar works of the same period from other museums have been taken into consideration as a reference.
During the AR experience, the user can select the reconstructed parts by clicking on the touchscreen. A detailed description of the specific element appears: the selected element turns red, and an audio track begins as it is transcribed on a text panel [Castagna 2021, pp. 23-72].
The last experimentations proposed in this paper are the models of the atrium's vaulted system of Palazzo Mazzonis, the seat of the museum (Fig. 5).
After the survey with TLS technique, the point cloud was used to obtain an ideal virtual model of the vaulted system covering this space through sectioning with vertical longitudinal and transverse planes. This model was then used to devise two real models with different purposes.
In the first model, the sections have been transformed into real tangible interlocked planar slices, made of cardboard with the 2D cutting device Trotec Speedy 400® of ModLab Arch of Politecnico di Torino. This model, with a purely didactic function, emphasizes the perception

Fig. 3. Ni-tennō and Kōnjikidō: a) virtual model b) virtual reconstruction; c) AR experience; d) VR experience (by S. Tamantini).

Fig. 4. Buddha Gupta: a) virtual acquired model; b) virtual reconstruction of missing part; c) AR experience (by L.Castagna).

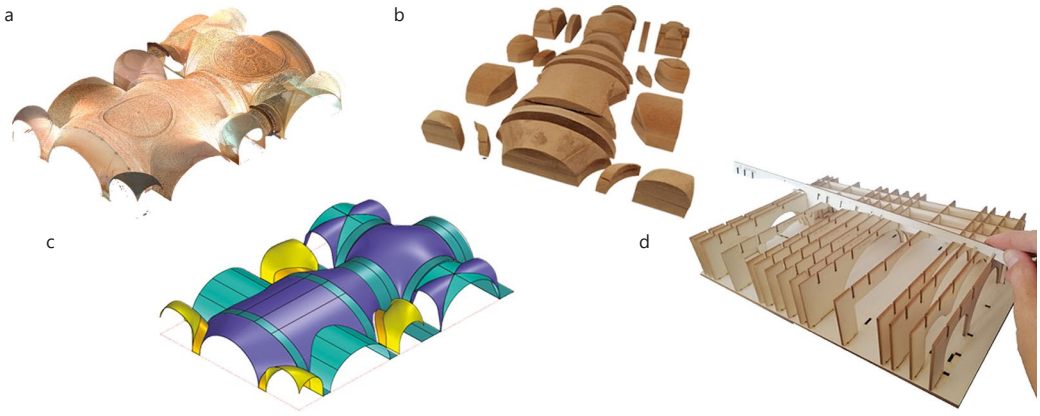

Fig.5. Palazzo Mazzonis atrium vaulted system: a) point cloud; b) virtual model; c) CNC milled model; d) laser cut model (by F. Ronco).

of the vaulted system of the atrium from bottom to top. Observing the waste material of the cutting process, a new model with the voids and solids reversed has been conceived. This handy object, fabricated with a CNC milling machine, allows perceiving the intrados surface of the vaults from above, in the perspective of tactile fruition [Ronco 2021, pp. 49-61].

Conclusion

The examples reported here want to be an example of the multiple possible uses of virtual models obtained with digital surveys in a perspective of interactive and inclusive use.
The collaboration with the museum is in continuous evolution and offers continuous opportunities to experiment with the languages of representation applied to the accessibility of the museum heritage. Only the integration of the applications presented can allow the involvement of the widest possible audience.
The research group formed between the Polytechnic of Turin and the MAO serves as an exchange, a catalyst for innovative ideas, and a means for knowledge circulating at the intersection of arts, management and technology. It represents a resource that leads to the innovative, effective and efficient integration of technology in the museum. Using VR, AR, tactile models and other cross-media techniques serves to deepen the relationship between a museum and its patrons.
The multidisciplinarity of the project represents on one side a great richness, on the other side requires a special effort on the part of those involved, which could be solved by systematizing collaborations and formalizing a research group across the academic and museum worlds. This would allow for cost containment, continuous updating on technologies and the involvement of specialized staff.
Finally, collaboration with local companies in the field of information technology and digital fabrication would allow for a broader range of experimentation possibilities.
The proposed experiences, therefore, will need to be validated with different categories of users, and in particular tactile models with visually impaired people. Thanks to the help of Dr. Franco Lepore, Disability Manager of the Municipality of Turin, and Arch. Rocco Rolli, founder of Tactile Vision Onlus, test groups will be constituted to verify the effectiveness of all the tactile models produced.
Another interesting development would be the hybridization of AR, VR and digital fabrication technologies to generate exciting new outputs.

Attributions

This paper, whose authors shared the methodological framework, was written by Francesca Ronco (par. Multilevel experiences; Museum of Oriental Art; workflow; AR...museum spaces and artwork) and by Rocco Rolli (par. accessibility).

Notes

[1] The students Serena Tamantini, Lorenzo Castagna and Luca Lombardi are coordinated by professors Roberta Spallone (Politecnico di Torino – DAD) and Fabrizio Lamberti (Politecnico di Torino – DAUIN), Luca Maria Olivieri (Università Ca' Foscari di Venezia), by the research fellow arch. Francesca Ronco (Politecnico di Torino – DAD, MODLab Design) and the MAO conservators Dr. Marco Guglielminotti Trivel and Dr. Claudia Ramasso.

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