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DIGITAL TECHNOLOGIES APPLIED TO THE ACCESSIBLE MANAGEMENT OF MUSEUMS. THE FIRST EXPERIMENTS CARRIED OUT AT THE MUSEUM OF ORIENTAL ART OF TURIN

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Abstract

The proposed research focuses on the museum context of the city of Turin (Italy), within an ongoing framework agreement between the Politecnico di Torino and the Museum of Oriental Art (MAO). It aims at the construction of a model for the management of the workflow that includes the digital survey, the 3D virtual modelling and the digital fabrication of the tactile models of the artworks and the exhibition spaces. The paper starts with an overview on the methods of conservation and dissemination of cultural and architectural heritage, on the accessibility of museums and on tactile perception and graphics. It presents the first outcomes of the designed workflow with a special focus on the digital fabrication experiments on the vaulted system of the atrium of Palazzo Mazzonis (MAO home). The founding idea is that tactile exploration of artifacts helps the visitor engagement, making the museum experience more educationally incisive and more inclusive, in a "Design for All" perspective.

Key words: CH Accessibility; Museum; Tactile graphics; Haptic perception; Prototyping.

Resumen

La investigación propuesta se centra en el contexto museístico de la ciudad de Turín (Italia), dentro de un acuerdo marco en curso entre el Politecnico di Torino y el Museo de Arte Oriental (MAO). Su objetivo es la construcción de un modelo para la gestión del flujo de trabajo que parte de la digitalización de las obras de arte y de los espacios y termina con la realización de modelos táctiles. El artículo comienza con una visión general sobre los métodos de conservación y difusión del patrimonio cultural y arquitectónico sobre la percepción y los gráficos táctiles. Presenta los primeros resultados del flujo de trabajo diseñado, centrándose especialmente en los experimentos de fabricación digital en el sistema abovedado del atrio del Palazzo Mazzonis (casa del MAO). La idea básica es que la exploración táctil de los artefactos ayuda a la participación del visitante, haciendo que la experiencia del museo sea más incisiva desde el punto de vista educativo y más inclusiva, en una perspectiva de "Diseño para todos".

Palabras clave: Accesibilidad del patrimonio cultural; Museo; Gráficos táctiles; Percepción háptica; Creación de prototipos

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1. INTRODUCTION

In recent years, the development of 3D technologies has generated important results in the field of Cultural Heritage.

Research in this field has produced and continues to promote, on the one hand, the birth and creation of digital archives, with the consequent delocalization of works from the museum and, on the other hand, the realization of in situ accessibility projects, thus physically opening the doors to the widest possible audience.

Today, the availability of digital scanning and the process of digital design and fabrication opens up possibilities for automation that allow the reproduction of objects in different formats, facilitating access to cultural heritage. Museums represent the domain where the concept of CH 'usability' has always manifested itself, a perfect context to explore the enormous potential of these modern technologies, offering new experience opportunities.

Both virtual and physical products aim to increase accessibility to meet different needs of users related to different factors of age, physical, sensory and cognitive abilities, education, culture and experience. Extending CH accessibility to people with disabilities is a current issue of great importance. Physical, sensory, and cultural accessibility should be considered essential to making cultural venues fully accessible to all visitors.

The hypothesis of this research is based on the recognition of the benefits that the visitor can achieve through a multisensory and immersive visit path. The challenge consists in the identification of a workflow that begins with recording the shape of the object and ends with its physical reproduction. The main question is how to reproduce models and informational materials that are suitable to be explored and understood during the tactile experience.

3D models of statues or architectures are very useful tools to engage people, especially suitable for users with special needs, such as blind people, who rely on the sense of touch to perceive objects.

The overall goal is to propose a multisensory exhibition model that takes into account this often neglected audience, expanding the field of research on all the experiential possibilities of the museum offer, beyond the visual.

2. METHODS OF CONSERVATION AND DISSEMINATION OF CULTURAL AND ARCHITECTURAL HERITAGE: STATE OF THE ART

The state of the art of methods of conservation and dissemination of cultural and architectural heritage is closely linked to technologies available to researchers in recent years. The use of electronic equipment allows performing some very precise survey operations that do not replace the traditional procedures of data acquisition but enrich them recording higher-level information content. Digitization systems of works using optical technologies, ensuring the integrity of the surveyed works, are gaining more and more importance (Díaz Gómez et al. 2012: 29–37). These include 3D digitization techniques based on laser and light stripes projection, also called structured white light. The use of these technologies allows the acquisition of very complex shapes (also related to "free-form" geometries), data about the investigated surface (smoothness, roughness, etc.) and colour information (Bo et al. 2019: 1–11). An alternative to these optical technologies is photogrammetry, which creates 3D models from simple 2D images. Therefore, the required instrumentation simply consists of a camera, a tripod, and possibly a set of lights. This allows any person with a good computer and a good camera to create three-dimensional models with photogrammetry programs in fairly automatic way.

The point cloud, obtained through a process of photogrammetry or laser scanning, can be saved and archived, returning the real state of an object in a given space-time context, allowing manipulation and measurement without physical contact with it. The digital models obtained can be shared in several ways (Barberà Giné 2017: 153–162). One of the simplest methods is to create a .pdf file using the Adobe Acrobat® 3D visualization tool. Certainly, the most effective way for artistic heritage valorization is represented by online platforms, such as Sketchfab, which allow totally interactive and free fruition. Digitized works are also used for the creation of virtual videos/stories, often equipped with graphic information (Díaz Gómez et al. 2012: 29–37). These three-dimensional models, modifiable and reproducible, are also used for purposes of data collection, analysis, and expansion of museum offerings, through the experience of physical replicas (Balletti & Ballarin 2019: 285–313).

3. THE ACCESSIBILITY OF ARCHITECTURAL AND CULTURAL HERITAGE IN MUSEUMS

Since the end of the 21st century, communication and involvement of the public have progressively become central to museums.

In Italy, the 1971 conference “The museum as a social experience” decreed the end of the conception of the museum as elite heritage, paving the way towards a more democratic vision of access to culture (Bruno 2019: 297–325). This trend was subsequently confirmed at the international level by the UN Universal Declaration of Human Rights (art 27.1) and reaffirmed by the Council of Europe Framework Convention on the Value of Cultural Heritage for Society, the so-called *Faro Convention* of 2013 (Montella et al. 2016: 13–36).

In Spain, the association *Organización Nacional de Ciegos Españoles* (ONCE), founder of the *Madrid Typhlological Museum*, has been working for almost a century to ensure services for blind people or people with severe visual impairments. Among the research carried out by the association and its publications there are more general ones that deal with European policies about access to culture by people with disabilities and those related to museum accessibility for the blind and visually impaired, in which European case studies and project proposals for access to content and container are reported (García Lucerga 1993, Pérez de Andrés & Ramos Fuentes 1994).

Cutting-edge museum institutions are beginning to recognize modern technologies as a means of adding new methods of “reading” to more traditional visitor paths (Petrelli et al. 2013: 58–63, Wilson et al. 2017: 445–465). Museums are increasingly offering multilevel and multisensory experiences, including not only sight, but also the senses of touch, smell, and hearing, which equally contribute to our knowledge of the reality around us. Contemporary museums pay particular attention to the manipulation of objects, whether physical or virtual, as it creates a stronger connection between the individual and the object than simply watching it.

3.1 ITALIAN RESEARCH

Several Italian scholars in the discipline of representation have carried out very interesting and multidisciplinary research projects on the study and modelling in 3D for museum exhibition purposes. Among them, particularly stimulating is the work carried out by Paolo Clini and his multidisciplinary research group at the *Museo Archeologico Nazionale delle Marche* in 2017 (Clini et al. 2018: 97–113). The proposed project is based on the fruition paradigm of “learning by interacting”, which allows going beyond the traditional forms of presentation/observation of heritage through showcases, stimulating the visitor to become an active spectator. Overall, the project allows for a direct connection between traditional information and the digital “copy” of the artefact.

Another Italian reference in this field is the research conducted by Alberto Sdegno, at the Department of Engineering and Architecture of the Università di Trieste, on some significant works of art, using the most sophisticated declinations of research tools from advanced modelling to three-dimensional scanning, 3D printing (Fig. 1), and interaction experiences offered by Augmented Reality technologies (Sdegno 2018: 257–272).

Fig. 1. The “grimaces of madness” by Franz Xaver Messerschmidt: a) Photomicrograph interpolation 3D scanning stage; b) Installation of 3D printed copies of the two sculptures at the Coronini Cronberg Foundation of Gorizia. (Source: Sdegno 2018: 266-269).

In the field of the discipline of Museology, the case of *Museo Facile* is particularly significant, a project conducted since 2012 by the Department of Humanities of the Università di Cassino e del Lazio Meridionale. This project focuses on communication and cultural accessibility, proposing an integrated system of communication that combines traditional tools with the use of teaching aids and assistive technologies (QR Code, video in Italian Sign Language LIS, thermoformed panels and tactile models) (Bruno 2019: 297–325). It is based on a rigorous study of the museum spaces to build an “easy” path able to meet the needs of different audiences. Interdisciplinary comparison and participatory planning represent the methodological premises of the project. The model has been tested and applied at the H.C. Andersen Museum in Rome, at the Museum of the Abbey of Montecassino and in the recent project “Luoghi del Contemporaneo a Cassino”.

3.2 INTERNATIONAL MUSEUMS OFFER

Research about the main museums offers at the international level, with the exception of those specifically dedicated to tactile experiences (*Museo Statale Omero* in Ancona, *Museo Anteros* in Bologna, *Museo Tiflologico* in Madrid), reveals heterogeneous attention to tactile sensory accessibility.

Some museums simply allow small groups of people to partially touch the collection, often with the help of staff or escorts (*Uffizi Gallery*, Florence; *Metropolitan Museum of Art*, New York). In other cases, there are only descriptive tours with dedicated guides (*Rijksmuseum*, Netherlands; *National Gallery of Art*, New York). The *Van Gogh Museum* also offers a workshop, to be held in a separate room from the traditional tour, with a three-dimensional reproduction of the famous painting “Sunflowers”. The *Guggenheim Museum* in New York takes the same approach, organizing monthly dedicated tours and workshops.

Others include some tactile supports (diagrams, Braille) or large print descriptions for the visually impaired that visitors can request at the ticket office or print directly at home (*National Gallery* in London, The *Tate Modern* in London). The *British Museum* offers, in addition to all this, the possibility of tactilely exploring nine works of the Egyptian sculpture gallery, through a “Guided Touch Tour” or independently, with support material provided at the ticket office. This museum also provides audio descriptions that can be downloaded from the website and listened directly from the user’s smartphone.

The *Louvre* in Paris provides a specially designed Touch gallery (handrails all along the way, plaques in Braille, French and English) that houses replicas of ten sculptures in a space specifically designed to ensure accessibility, even on their own, for the visually impaired user. This gallery is not separate from the rest of the museum and is open to anyone, representing an educational space useful to all.

In 2015, the *Museo Nacional del Prado* in Madrid launched the Touch the Prado exhibition that included the possibility of touching the relief images of six pictorial works of different genres, as well as enjoying educational materials (Braille texts and audio guides).

In 2018, the *National Gallery* in Prague hosted the temporary exhibition “Touching Masterpieces by Geometry” in which digital models of some iconic sculptures (Michelangelo’s David, Venus de Milo, and Nefertiti) could be tactilely explored with special haptic gloves that control the hands in virtual space, returning vibrations when the object is intercepted.

The permanent exhibition at the *Louvre* in Abu Dhabi is particularly interesting. Opened in 2017, it houses different haptic stations, created by “Tactile Studio”, containing a description of the represented object, to which a Braille translation and a reproduction of the tangible object are added. On the panel, there are also some enlarged details of the object, to guarantee and facilitate its fruition (Fig. 2).

Apart from the last example in Abu Dhabi, the approach is often to treat the tactile experience as something separate from the normal visit. This probably occurs both because attention to this type of accessibility is a relatively recent issue that many museums have found themselves dealing with in the process, and because there are no shared guidelines in this regard.

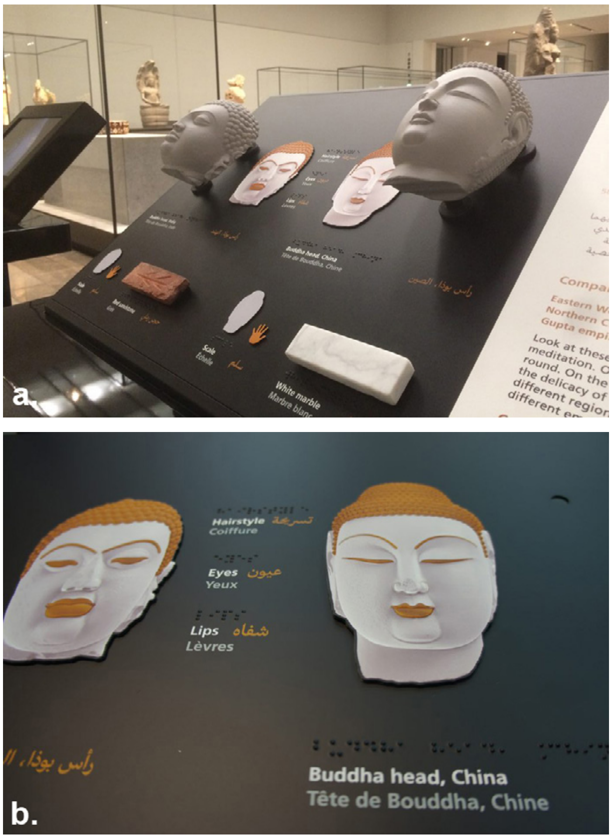


Fig. 2. Louvre Abu Dhab, haptic station of Buddha Head by Tactile Studio; a) the general layout; b) zoom on tactile graphics (Source: http://tactilestudio.it/louvre-abu-dhabi-2017/)

3.3 TECHNOLOGIES FOR VISITOR ENGAGEMENT

Despite this fragmentary museum panorama, there is an emerging trend toward mixed inclusion techniques that involve both tactile exploration and audio description.

There are several examples where digital fabrication has been combined with other technologies, creating multisensory and educational experiences. The following is a schematic list of them:

- Tooteko (D'Agnano et al. 2015: 207-213) is an app that uses NFC technology to provide audio descriptions of the façade of a 15th-century church in Italy, linked to its digitally fabricated survey;
- 3DPhotoworks (Photoworks n.d.), a U.S. company, which produces colored tactile prints that, for the "Sight Unseen" exhibition at the Canadian Museum for Human Rights, incorporated tactile sensors that trigger sound descriptions;
- The University of Vienna (Candling 2010) conducted research on converting 2D and 3D artefacts into tactile replicas, which were then enhanced with an audio guide, tactile guidance system, and relief diagrams;
- Applications that used 3D printed interactive models equipped with sensors such as cameras (Reichinger 2016: 91–100), capacitive sensors, and microphones (Shi et al. 2016: 4896–4907);
- The "Orasis" project uses 3D printed exhibits, connected tactile sensors, Arduino boards, and a mobile app to improve museum access for blind users (Anagnostakis et al. 2016: 1021–1025);

3D puzzles from the "Brighton Museum and Art Gallery" that focus on the educational purpose of replication and the educational and communicative aspect of the CH experience, proposing a playful use of it (Samaroudi 2017: 201–206).

These experiences testify that, without a doubt, one of the goals of applied research is to create "sensorized" models (Reichinger 2012: 497–504). Replicas and digitally fabricated models must increasingly be joined by other technologies to create significant added value in the museum context, confirming the need for a multidisciplinary approach to ensure the greatest possible accessibility to museums and cultural heritage in general.

These examples represent a point of reference for this research, offering didactically "interactive" paths, through the integration of different representation tools and giving space to moments of tactile exploration.

4. NOTES ON TACTILE PERCEPTION AND THE VALUE OF MANIPULATION AS COGNITIVE TOOLS

Touch is a realistic, concrete, and sequential sense and is considered the sense that first induces us into the world and last leaves us. The similarity between tactile and optical behaviors calls for a careful examination of the compensatory processes of the human mind, especially when integrated use of the residual senses replaces vision. Through the contact of the hand with lines, surfaces and volumes in relief it is possible to redraw an image and to know a composition. In the mind vision is elaborated from the connection of sensory perceptions and knowledge, whether its optical or tactile nature (Secchi 2018: 15–31). Tactile perception becomes of fundamental importance for blind and visually impaired people, assuming a gnostic function and becoming a real active tactile exploration, systematic and intentional, also called haptic exploration. It involves harmonious coordination of the two hands in place of the hand-eye coordination of the sighted.

Haptic exploration takes longer than visual exploration because it requires a sequence of perceptual acts that are synthesized only later in a global representation.

Because of the peculiarities of the specificity of haptic perception, several scholars have addressed the issue of representation and relief graphics, trying to systematize and codify it.

The growing interest in tactile representation or "relief drawing" has produced numerous studies and research to establish what should be the basis of a unified codified language (Empler 1996).

Starting in the 1990s, in Italy, in the scientific disciplinary field of "drawing" there have been several studies and publications on the perceptual and representational modalities for the visually disabled (De Rubertis 1996, Levi & Rolli 1994, Brie & Morice 1996).

In the new millennium, the interest in these issues is confirmed by the studies of Lamberto Nasini and Hasan Isawi (Nasini & Isawi 2006), of Tommaso Empler and Alexandra Fusinetti (Empler 2013, Empler & Fusinetti 2019) and by the Summer School organized in September 2018 by the Unione Italiana Disegno (UID) on the theme "Rilievo dei Beni Culturali e rappresentazione inclusiva per l'accessibilità museale" (Amoruso 2019: 261–264).

In the normative field there are now several ISOs concerning the "normalization" of characters and symbols, however, emerges a certain heterogeneity of research areas and results that affect the field. To date has not yet reached a codification of the system of signs and meanings attributed to visual-tactile messages used and an organization of the same visual-tactile panels.

Communication for the visually impaired and blind has not yet had an effective procedural and graphic systematization; for this reason, a "system of codes" is necessary both for three-dimensional and two-dimensional models, for which methodologies and methods of execution must be identified.

The definition of a codification of visual-tactile symbology requires an in-depth knowledge of the characteristics of the sense of touch, with particular reference to haptic perceptibility, and of the mental processes of memorization of information acquired by a visually impaired person by that means.

5. THE MUSEUM OF ORIENTAL ART OF TURIN

5.1 THE RESEARCH FRAME

The proposed research focuses on the museum context of the city of Turin (Italy), within an ongoing framework agreement between the Politecnico di Torino and the Museum of Oriental Art (MAO) that aims to build an accessible exhibition route that includes tactile models of the architectural spaces and a small part of its collection.

This work started from an 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. The research group, coordinated by Roberta Spallone and Marco Vitali of the Polytechnic of Turin and with the participation as visiting professor of Concepción López, of the Polytechnic of Valencia, implemented the research work carried out in recent years (Spallone & Vitali 2017), on complex

Fig. 3. Palazzo Mazzonis' vaulted atrium (Source: own's).

systems of brick vaults in Baroque buildings in Piedmont with data derived from a metric survey campaign led by Concepción López and carried out by terrestrial laser scanner (TLS). Among the spaces surveyed by the group, there are the atrium (Fig. 3), the staircase and the hall of honor of Palazzo Mazzonis, home of the MAO.

5.2 THE RESEARCH AIM

The research project is therefore inserted in this gap of the exhibition offer. After a careful analysis of the technologies for surveying and digital fabrication, of the studies and applications of multisensory pathways in museums and perceptive modalities beyond the sight, the main aims are:

- the identification of a workflow that starts from the digital acquisition and has as its objective the realization of a tactile model/ replication made with the techniques of digital fabrication;
- the realization of an inclusive and multisensory exhibition path, modular and implementable, including the description of the architectural/ exhibition spaces and a selection of works.

5.3 MAO: THE “CONTAINER” AND THE “CONTENTS”

MAO is one of the most important and dynamic realities in the Italian panorama in the field of presentation, valorization and diffusion of Asian arts and cultures.

It is located in Palazzo Mazzonis, a baroque building (1639) that, during the 18th century, after various interventions, assumed the current shape. It is constituted by a central part and other two parts embracing the central inner courtyard, linked to the road by a great colonnaded atrium. This atrium, adorned by an elegant stone colonnade, is connected by a sumptuous two flights staircase to the hall of honor at the first floor. These spaces are the only ones that have largely maintained original structure, even if with some modification to the decorative apparatus.

Regarding the content, MAO today boasts a collection of 2500 works coming from many countries of Asia and belonging different historical periods and 1400 finds from the excavation of archaeological sites in the Iraqi areas of Seleucia and Coche, from the pre-Islamic period (up to before 63 B.C.). To manage this vast heritage, the collection has been divided into five macro-areas (South Asia, Southeast Asia, China, Japan, Himalayan Region, Islam), according to the historical and geographical belonging (Bruno & Ricca 2010: 3-24).

Since its opening to the public at the end of 2008, MAO has paid attention to digital technologies for the communication of its heritage, particularly at a distance. It is present on the web in various forms (dedicated website, social pages, YouTube channel, Google Arts and Culture). On the other hand, the visit in presence of the permanent collections of the MAO makes limited use of multimedia elements (audio guides) and does not include the use of other supports that would guarantee inclusive access (tactile models, dedicated audio descriptions, descriptions in LIS language).

6. THE WORKING METHODOLOGY AND PARTIAL RESULTS

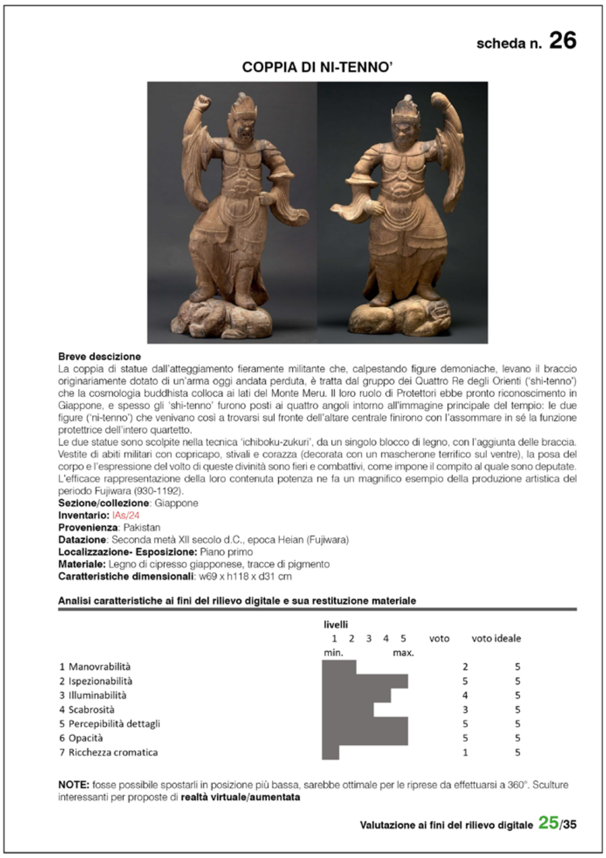
The proposed workflow is appropriate for both the container (exhibition spaces) and the content (artworks) of the museum. It starts from the digital survey of the object arriving at the digital fabrication of it, passing through the 3D virtual modelling.

The project includes the before mentioned architectural spaces and five artworks (one for each geographical collection area) selected following these parameters: maneuverability and inspectability; illuminability; roughness; perceptibility of details; opacity; chromatic richness (Fig. 4).

The following step is the digital survey and its return in virtual model. The survey was done with two different techniques: photogrammetry for the works (Fig. 5) and terrestrial laser scanner (TLS) for the spaces (Fig. 6).

Currently, the fabrication of the artworks’ replicas hasn’t yet begun. On the other side, a virtual model and two types of digitally fabricated models of the atrium vaulted system have been realized.

The maquettes, both at a scale of 1:50, consist of “illustratives” models, morphologically similar to the object acquired, instead of its exact copy. The virtual and physical modelling has been started from the cutting of the point cloud with 22 section planes (Fig. 7, Fig. 8).



scheda n. **26**

COPPIA DI NI-TENNO'

Breve descizione
La coppia di statue dall'atteggiamento fieramente militante che, calpestando figure demoniache, levano il braccio originariamente dotato di un'arma oggi andata perduta, è tratta dal gruppo dei Quattro Re degli Orienti ('shi-tenno') che la cosmologia buddhista colloca ai lati del Monte Meru. Il loro ruolo di Protettori ebbe pronto riconoscimento in Giappone, e spesso gli 'shi-tenno' furono posti ai quattro angoli intorno all'immagine principale del tempio: le due figure ('ni-tenno') che venivano così a trovarsi sul fronte dell'altare centrale finirono con l'assommare in sé la funzione protettrice dell'intero quartetto.
Le due statue sono scolpite nella tecnica 'ichiboku-zukuri', da un singolo blocco di legno, con l'aggiunta delle braccia. Vestite di abiti militari con copricapo, stivali e corazza (decorata con un mascherone terrifico sul ventre), la posa del corpo e l'espressione del volto di queste divinità sono fieri e combattivi, come impone il compito al quale sono deputate. L'efficace rappresentazione della loro contenuta potenza ne fa un magnifico esempio della produzione artistica del periodo Fujiwara (930-1192).
Sezione/collezione: Giappone
Inventario: IAs/24
Provenienza: Pakistan
Datazione: Seconda metà XII secolo d.C., epoca Heian (Fujiwara)
Localizzazione- Esposizione: Piano primo
Materiale: Legno di cipresso giapponese, tracce di pigmento
Caratteristiche dimensionali: w69 x h118 x d31 cm

Analisi caratteristiche ai fini del rilievo digitale e sua restituzione materiale

	livelli 1 2 3 4 5 (min. – max.)	voto	voto ideale
1 Manovrabilità		2	5
2 Ispezionabilità		5	5
3 Illuminabilità		4	5
4 Scabrosità		3	5
5 Percepibilità dettagli		5	5
6 Opacità		5	5
7 Ricchezza cromatica		1	5

NOTE: fosse possibile spostarli in posizione più bassa, sarebbe ottimale per le riprese da effettuarsi a 360°. Sculture interessanti per proposte di **realtà virtuale/aumentata**

Valutazione ai fini del rilievo digitale 25/35

Fig. 4. Overview of the evaluation sheet for the surveyed work "Ni-Tenno sculpture" (descriptive content taken from the MAO's internal files: M. Guglielminotti, C. Ramasso, editing: F. Ronco.

Fig. 5. Photo alignment with sparse cloud in Agisoft Metashape® software (photos: F. Ronco, S. Tamantini).

In the first model, these sections have been transformed in real tangible interlocked planar slices. Such slices have been fabricated with the 2D cutting device Trotec Speedy 400® of ModLab Arch of Politecnico di Torino, employing relatively inexpensive material (such as cardboard) and then assembled through a sequence of manual operations (Fig. 9, Fig. 10).

Fig. 6. Point cloud of Palazzo Mazzonis atrium. (Source: scan by M. C. López González; processing by F. Natta).

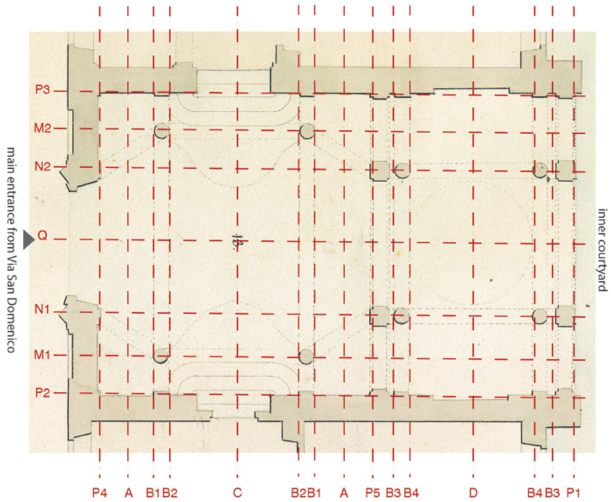


Fig. 7. Excerpt of the survey drawing of Palazzo Mazzonis, 1st July 1845. (Source: Archivio Storico del Comune di Torino, Tipi e dis., cart. 63, fasc. 9, dis. 1, tav III. Graphic processing by F. Ronco).

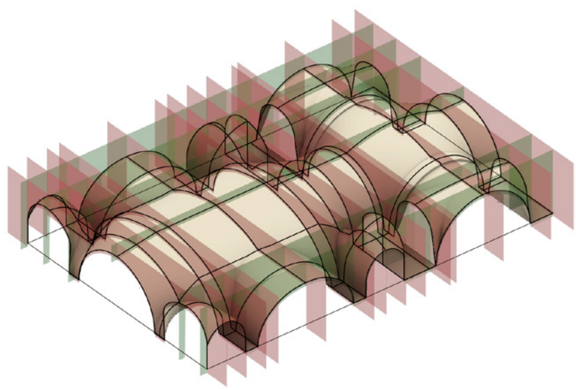


Fig. 8. Palazzo Mazzonis Atrium: axonometry of virtual model elaborated starting from the point cloud, section plans and intersection lines (Source: 3D modelling and graphic processing by F.Ronco).

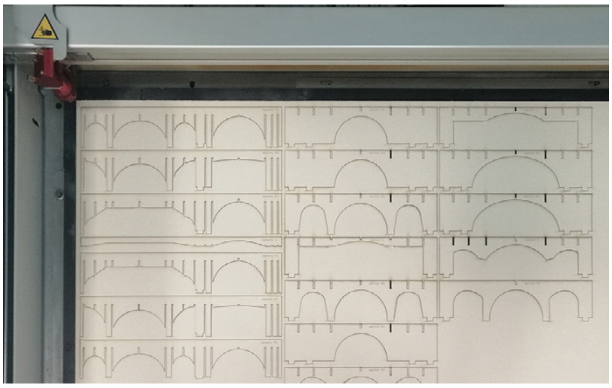


Fig. 9. Palazzo Mazzonis Atrium vaulted system maquette. Sections realized with laser cut printer on natural cardboard. (Source: modelling and processing by F. Ronco).

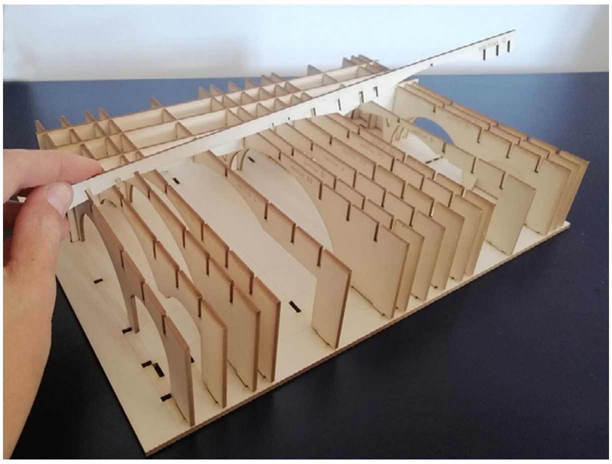


Fig. 10. Palazzo Mazzonis Atrium: maquette mounting process, joint between transversal and longitudinal sections. (Source: own's. Digital fabrication and mounting by F. Ronco).

This model, with a purely didactic function, emphasizes the perception of the vaulted system of the atrium from bottom to top (Fig. 11), but observing the waste material of the cutting process, some considerations can be done. A new model with the voids and solids reversed can be designed. In this way, the user could perceive the surface from above. The second model is based on this observation, in the perspective of tactile fruition.

In the second model, sections have been used to build the virtual 3D interpretative model with Rhinoceros® 7. The spaces are represented in negative to obtain a handy object that allows perceiving the intrados surface of the vaults from above.

Fig. 11. Palazzo Mazzonis Atrium: mounted maquette, inner view. (Source: own's).

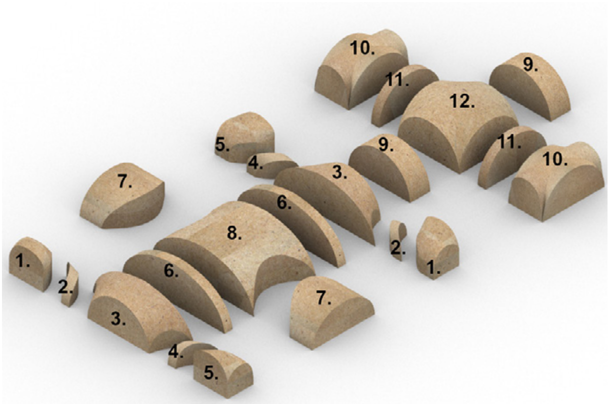


Fig. 12. Palazzo Mazzonis atrium 3D model (Rhinoceros®): different puzzle pieces (Source: own's. Modelling by F. Ronco).

The vaulted system consists of ten different types of arches and vaults: trapezoidal-based sail vaults (3), arches with a curved plan (2, 4), angular sail vaults (1, 5); arches (6, 9, 11), lintels, square-based sail vault (12), and cross vaults (10) (Fig. 12).

Each of these parts (except the arches) was then subdivided into additional portions for fabrication constraints, to facilitate its realization with a numerical control milling machine. The need was to have at least one flat face to place on the work plan and to avoid moving or rotating the machined piece for further operations. The division operations were carried out manually, even if algorithms for automatic division exist (Muntoni et al. 2019: 17-28). The solids of the various portions have been cut with horizontal planes, at a different distance according to the thickness of the MDF panel to be used (10, 14 or 1 mm).

The Medium Density Fiberboard (MDF) model has been fabricated with Biemmepi – FP3 CNC milling machine.

Fig. 13. Palazzo Mazzonis atrium MDF physical model of the vaulted system aimed to tactile experience of the vault (Source:own's, Digital fabrication by F. Ronco).

For each portion of the atrium, a single block has been obtained through the assembly phase. The final model will allow both a global perception of the surface of the vaulted system from above (assembled configuration) and a deeper understanding of the geometry of the single vaulted portion (divided configuration) (Fig. 13).

7. CONCLUSION

This research aims at the construction of a model for the management of the workflow from the digitization of the work and the exhibition spaces to the realization of the tactile replica. Currently, we are facing a lack of research about workflows and methodologies of creation of such replicas, leaving open many questions about issues like scale, choice of materials and even ways to present them to the public. The physical properties of the replicas and ways of presenting them to the public must be adequately addressed prior to the implementation of this large-scale approach (Wilson et al. 2017).

From a social and economic perspective, there is no question that tactile exploration of artefacts helps the visitor understanding and engagement. In addition, the tactile experience accompanied by audio descriptions, holds great value making the museum experience more educationally incisive and more inclusive, in a "Design for All" perspective.

The sense of the creation of a model and a shared language is to reduce the errors of assessment by museum institutions on accessibility issues and to facilitate users in the tactile experience so that it becomes increasingly automatic and does not require introductions and explanations.

Here I have presented the early stages of this research. MAO represents a great opportunity to test different digital survey and fabrication techniques, at different scales.

The prototypes presented have two different purposes, the first (sliced one) has a more didactic function, explanatory of the geometries generating the vaulted system, the second goes in the direction of tactile enjoyment. Obviously, once its effectiveness has been established, the second model will have to be enriched by tactile graphics and accompanied by audio descriptions, similarly to what previously presented.

The obtained models will need to be continuously tested by visually-impaired people and, 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.

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REFERENCES

Amoruso, G. 2019. "UID PhD Summer School. Rilievo del patrimonio culturale e rappresentazione inclusiva." *Diségno*, no. 4, pp. 261–264. ISSN 2533-2899.

Anagnostakis, G., Antoniou, M., Kardamitsi, E., Sachinidis, T., Koutsabasis, P., Stavrakis, S., Vosinakis, M., Zissis, D. 2016. "Accessible museum collections for the visually impaired: combining tactile exploration, audio descriptions and mobile gestures." In Proceedings of the 18th *International Conference on Human-Computer Interaction with Mobile Devices and Services Adjunct (MobileHCI '16)*. New York: Association for Computing Machinery, pp. 1021–1025. https://doi.org/10.1145/2957265.2963118

Balletti, C., Ballarin, M. 2019. "An Application of Integrated 3D Technologies for Replicas in Cultural Heritage." *ISPRS Int. J. Geo-Inf.*, no. 8, pp. 285–313. https://doi.org/10.3390/ijgi8060285

Barberà Giné, A. 2018. "Fotogrametría para la conservación-restauración de bienes culturales." *Unicum,* no. 17, p. 153-162. ISSN: 1579-3613.

Bo, P., Pottmann, H., Kilian, M., Wang, W., Wallner, J. 2011. "Circular arc structures." *ACM Trans. Graph.*, vol. 30, no. 4, pp. 101: 1–11. ISSN 0730-0301. https://doi.org/10.1145/2010324.1964996

Brie, M, Morice, J.C. 1996. "Il disegno in rilievo: oggetto di conoscenza" *XY, Dimensioni del Disegno*, no. 26, pp. 38–51.

Bruno, A., Ricca, F. 2010. *Il Museo d'Arte Orientale MAO*. Torino: Allemandi, pp. 3–24. ISBN 978-88-422-1699-5.

Bruno, Ivana. 2019. "Comunicazione e accessibilità culturale. L'esperienza di Museo Facile". *Il capitale culturale*, no. 20, pp. 297–325. https://doi.org/10.13138/2039-2362/2068

Candling, F. 2010. *Art, Museums and Touch*. Manchester: Manchester University Press. ISBN 978-0719079337

Clini, P., Frapiccini, N., Quattrini, R., Nespeca, R. 2018. "Toccare l'arte e guardare con altri occhi. Una via digitale per la rinascita dei musei archeologici nell'epoca della riproducibilità dell'opera d'arte." In Luigini, Alessandro and Panciroli, Chiara eds. *Ambienti digitali per l'educazione all'arte e al patrimonio*. Milano: FrancoAngeli s.r.l., pp. 97-113. ISBN 9788891773333. http://library.oapen.org/handle/20.500.12657/25364 [accessed on 2020/05/04].

D'Agnano, F., Balletti, C., Guerra, F., Vernier, P. 2015. "Tooteko: A case study of augmented reality for an accessible cultural heritage. Digitization, 3D printing and sensors for an audio-tactile experience." *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Vol. 5W4, pp. 207–213. https://doi.org/10.5194/isprsarchives-XL-5-W4-207-2015

De Rubertis, R. (ed.) 1996. "Il disegno oscuro." *XY Dimensioni del Disegno*, no. 26.

Díaz Gómez, F., Jiménez Peiró, J., Barreda Benavent, A., Asensi Recuenco, B, Hervás Juan, J. 2015. "Modelado 3D para la generación de patrimonio virtual. 3D modeling for the generation of virtual heritage." *Virtual Archaeology Review*, vol. 6, no. 12, pp. 29–37. ISSN 1989-9947. https://doi.org/10.4995/var.2015.4150

Empler, T. 1996. "Il disegno in rilievo negli Istituti di Ricerca italiani e francesi." *XY, Dimensioni del Disegno*, no. 26, pp. 5–7.

Empler, T. 2013. "Universal Design: ruolo del Disegno e Rilievo." *Disegnare. Idee Immagini*, no. 46, pp. 52–63. ISBN 978-88-492-1835-0.

Empler, T., Fusinetti, A. 2019. "Rappresentazione visuo-tattile: comunicazione tattile per i disabili visivi." In Belardi, Paolo ed. UID per il disegno: 2019. *Riflessioni: l'arte del disegno/ il disegno dell'arte*. Roma: Gangemi, pp. 1563–1572. ISBN 978-88-492-3762-7. https://www.torrossa.com/it/resources/an/4557553 [accessed on 2020/05/04].

García Lucerga, M.A. 1993. *El acceso de las personas deficientes visuales al mundo de los museos*. Madrid: Organización Nacional de Ciegos Españoles, Sección de Cultura D.L. ISBN 84-87277-25-X. https://portal.once.es/bibliotecas/fondo-bibliografico-discapacidad-visual [accessed on 2020/05/04].

Levi, F., Rolli, R. 1994. *Disegnare per le mani. Manuale di disegno in rilievo*. Torino: Silvio Zamorani Editore. ISBN: 9788871580388.

Montella, M., Petraroia, P., Manacorda, D., Di Macco, M. 2016. In Feliciati, Pierluigi, ed. *La valorizzazione dell'eredità culturale in Italia*, Atti del Convegno (Macerata 5-6 novembre 2015), Supplemento, n. 5. Macerata: eum edizioni, pp. 13–36. ISBN 978-88-6056-485-6.

Muntoni, A., Nuvoli, S., Scalasc, A., Tola, A., Malomo, L., Scateni, R. 2019 "Mill and Fold: Shape Simplification for Fabrication." *Computer & Graphics*, n. 80, p. 17-28. ISSN 0097-8493. https://doi.org/10.1016/j.cag.2019.03.003

Nasini, L., Isawi, H. 2006. *Una geometria per comprendere lo spazio senza percepirlo visivamente*. Roma: Officina Edizioni. ISBN: 9788860490070.

Pérez de Andrés, C., Ramos Fuentes, A. 1994. *Museos abiertos a todos los sentidos: acoger mejor a las personas minusválidas*. Salamanca: Ministerio de Cultura, Organización Nacional de Ciegos Españoles, Sección de Cultura 1994. ISBN 84-87277-40-3. https://portal.once.es/bibliotecas/fondo-bibliografico-discapacidad-visual [accessed on 2020/05/04].

Petrelli, D., Ciolfi, L., Van DiJk, D., Horneker, E., Not, E., Schmidt A. 2013. "Integrating material and digital: A new way for cultural heritage." *Interactions: new visions of human-computer*, n. 20, pp. 58–63. https://doi.org/10.1145/2486227.2486239

Photoworks: 3D Photo Printing Products. URL: https://www.3dphotoworks.com/product [accessed on 2020/05/04].

Reichinger, A., Neumüller, M., Rist, F., Maierhofer, S., Purgathofer, W. 2012. "Computer-Aided Design of Tactile Models. Taxonomy and Case Studies." In Miesenberger, Klaus et al. (eds) Computers Helping People with Special Needs. ICCHP 2012. Lecture Notes in Computer Science, vol 7383. Springer, Berlin, Heidelberg, pp. 497–504. ISBN 978-3-642-31533-6. https://doi.org/10.1007/978-3-642-31534-3_73

Reichinger, A., Fuhrmann, A., Maierhofer, S., Purgathofer, W. 2016. "Gesture-Based Interactive Audio Guide on Tactile Reliefs." In *Proceedings of the 18th International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS '16).* New York: Association for Computing Machinery, pp. 91–100. https://doi.org/10.1145/2982142.2982176

Samaroudi, M., Echavarria, K.R., Song, R., Evans, R. 2017. "The Fabricated Diorama: Tactile Relief and Context-aware Technology for Visually Impaired Audiences." In *Proceedings of the Eurographics Workshop on Graphics and Cultural Heritage (GCH '17).* Goslar: Eurographics Association, pp. 201–206. https://doi.org/10.2312/gch.20171315

Sdegno, A. 2018. "Rappresentare l'opera d'arte con tecnologie digitali: dalla realtà aumentata alle esperienze tattili." In Luigini, Alessandro and Panciroli, Chiara eds. *Ambienti digitali per l'educazione all'arte e al patrimonio*. Milano: FrancoAngeli s.r.l., pp. 257–272. ISBN 9788891773333

Secchi, L. 2018. "Toccare con gli occhi e vedere con le mani. Funzioni cognitive e conoscitive dell'educazione estetica." *Ocula*, vol. 19, no. 19, pp. 15–31, https://doi.org/10.12977/ocula2018-9

Shi, L., Zelzer, I., Feng, C., Azenkot, S. 2016. "Tickers and Talker: An Accessible Labeling Toolkit for 3D Printed Models." In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16)*. New York: Association for Computing Machinery, pp. 4896–4907. https://doi.org/10.1145/2858036.2858507

Spallone, R., Vitali, M. 2017. *Star-shaped and Planterian Vaults in the Baroque Atria of Turin*. Ariccia: Aracne. ISBN 978–88–255–0472–9

Wilson, P.F., Stott, J., Warnett, J.M., Attridge, A., Smith, M.P., Williams, M.A. 2017. "Evaluation of touchable 3D-printed replicas in museums." *Curator. The Museum Journal*, vol. 60, no. 4, pp. 445–465. https://doi.org/10.1111/cura.12244

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