Tactile and Digital Narratives for a Sensitive Fruition of Bas-Relief Artworks

Francesca Picchio and Hangjun Fu

1 Introduction to Digital Museum Narrative

The development of increasingly inclusive and engaging narratives of works of art has now become a prerogative of museums, which, thanks to the massive use of digital technologies for both documentation and communication, are collectively moving towards a general rethinking of exhibition itineraries.

Narrating an artwork implies establishing a multitude of dialogues, with the artifact, with the author of the piece, with the space in which the work is experienced, and, finally, with the user of the work. Therefore, representing it digitally goes beyond the simple concept of reproduction and copying. Its interpretation, even simplified forms or new significances, transforms the artwork into something else [1]. And it is precisely this something else, augmented with information that are useful to describe the artwork from other points of view, that has to find its own narrative logic within the museum itinerary. The museum is no longer a container of artworks but a place where knowledge is gradually created. It uses new digital technologies to communicate new information contents and to initiate new ways of interaction between these contents and the subject who benefits from them (through immersion, virtual reality applications, augmented reality, etc.) [2]. In the action of communication between the designer and artwork, the designer seeks to establish a dialogue with the work to elaborate a form, i.e. a drawing. In this sense, reproduction should not be a sterile copy, but a basis for a critical and specific reading of its components, enhancing those forms that characterize its values and meanings.

F. Picchio (✉) · H. Fu
University of Pavia, 27100 Pavia, Italy
e-mail: francesca.picchio@unipv.it

H. Fu
e-mail: hangjun.fu@unipv.it

A. Giordano et al. (eds.), *Beyond Digital Representation*, Digital Innovations in Architecture, Engineering and Construction,
https://doi.org/10.1007/978-3-031-36155-5_17

The research experience presented is part of the development of a digital narrative of a sculptural work—as elaborate as it is complex—within an exhibition.

In particular, through the digitization of the original parapet of Donatello's pulpit in Prato, it was possible to start a reflection on the value of the 3D database and on the concept of copy, accessible both through its solid prototyping and its virtualization.

The premise for the research stems from the temporary absence of part of the work within the exhibition itinerary. On behalf of the itinerant exhibition Donatello, the Renaissance, the Ufficio Beni Culturali Musei Diocesani Prato and the Palazzo Pretorio Museum of the Municipality of Prato have temporarily loaned the artist's works, including two of the 15th-century pulpit panels, which will be exhibited in museums in Florence, Berlin, and London until 2023.

To overcome the temporary absence of the main examples of Donatello's work in Prato, from July 2021, the city's Ufficio Beni Culturali Musei Diocesani has promoted the creation of a temporary exhibition in the pulpit Hall in the Museum.

The research actions undertaken sought to fulfill a twofold purpose. On the one hand, the digitization of the original pulpit has been aimed at the production of a digital 3D database. This database, obtained by integrated image-based and range-based instrumentation, facilitated the production of drawings (vector reproductions, photomosaics, 3D models) aimed at an accurate and detailed description of the sculptural work. On the other hand, the generation of a database thus established made it possible to structure a digital presentation of the artwork through the use of 3D-printed models at different scales, as well as the use of the work from mobile devices, both on-site and remotely [3]. The two 3D-printed tiles of the pulpit fulfilled the task of visually filling the space left by the artworks on loan, with the possibility of being touched and enjoyed in a more stimulating and participative visit. Using augmented reality applications and markers placed near the pulpit, visitors can visualize the tiles on their mobile device and understand aspects not immediately perceivable by standard observation.

2 Foreword to Digitization for the Fruition of CH: The Case Study of Donatello's Pulpit

Donatello's pulpit, located on the right corner of the façade of St. Stephen's Cathedral in Prato, represents an architectural-sculptural work closely connected to the city and its relic, the Sacra Cintola. or Holy Girdle, the rope put by the Apostles around the Virgin's waist before her assumption into Heaven. On the occasion of the First Crusade (1096–1099), a nobleman from Prato, Michele Dagomari, in 1141 left the relic as a gift to the former Pieve di Santo Stefano, which, for this reason, it became a place of worship for the devotees. With the expansion of the church, due to the rapid and growing pilgrimage of the faithful, attracted by the Holy Girdle, the new pulpit was built in 1428. This element, which represents the last stage of the Ostension ritual,

Fig. 1 The external copy of the Donatello's pulpit, put in relation to the facade of the Santo Stefano Cathedral. Below, images from the decorative parapet (Editing: C. Rivellino)

was realized at the intersection of the south and west elevations of the Cathedral [4]. From this, even today, the Bishop shows the Holy Girdle to the crowd. (Fig. 1).

The artwork appears as a small round temple. Consisting of a 175 cm radius structure, placed more than 300 cm above the ground, the pulpit has an umbrella-shaped roof crowned by the statue of St Stephen, the city's patron saint. The circular marble parapet is composed of seven panels, separated from each other by pairs of fluted pilasters with Corinthian capitals. The refinement of the piece is mainly due to the decorative and sculptural tiles motif: a series of festive spirits, five per tile, joyfully dance for the Ostension of the Girdle, articulated on different depth backgrounds. To design them, Donatello was inspired by the figure of the putto, which in antiquity was believed to inhabit the paradise of Dionysus. The three-dimensional and dynamic effect, masterfully realized by Donatello in a thickness of a few centimeters, is made possible by the technique of stiacciato. The movement effect is amplified by a golden mosaic background that changes with the light effects, enhancing the Dionysian dances of the sprites. Unfortunately, the angular exposure of the artwork, which is strategic from a functional point of view, has also been the reason for its progressive deterioration. Since 1776, the artwork has undergone several restorations of its surface, which has been subject to constant erosion. The original pulpit was replaced in 1972 with a copy in resin and marble dust: this copy is the parapet currently visible on the right side of the Cathedral façade [5].

The original parapet, together with the bronze capital underneath, is now preserved in the Museo dell'Opera del Duomo (Fig. 2).

The undertaken documentation project, aimed at constructing a memory and a new digital narrative of Donatello's artwork, involved the copy—the external pulpit [6] and the original—the marble parapet displayed in the Museum rooms. The fast

Fig. 2 Images of the original marble parapet, conserved in the Museum of opera del Duomo di Prato. In the image above are visible the target positioned for integrated data acquisition (Photos: F. Picchio)

technological evolution applied to Cultural Heritage has provided increasingly accurate measurement tools but has also witnessed a substantial transformation in the type of databases. From such three-dimensional digital products, the drawer can read in detail the texture and imperfections of the material, its colorimetric component as well as its processing. About the communicative purposes to which the drawing must respond, processes of analysis, discretization, and segmentation of the data must then be implemented.

3 Procedures for the Production of Integrated Digital Databases

Donatello's original pulpit is located in the room of the same name in the Museum and is placed on a plinth 150 cm above the ground. Image-based (cameras) and range-based (laser scanners) instruments were used to make a digital duplicate of it. They have been applied to keep different distances between the instrument and the surface to be acquired, depending on both the performance characteristics and the communication goals to be achieved. To further increase the level of metric accuracy and textural detail, in parallel to the TLS Faro CAM2 S150 Terrestrial Laser Scanner and the Canon EOS 77D camera, the Artec Eva was used. This is a precision scanner that works with structured light to obtain metrically accurate and already textured 3D models of small and medium-sized objects.

Digital duplicates with a high level of detail have been produced for each of the seven parapet tiles, with reliability on the surface and material texture of the bas-relief in the millimeter range.

Thanks to the use of calibrated cameras and lenses, it was possible to obtain a photogrammetric model of the entire parapet, colorimetrically verisimilar to the different colors of the background mosaic and the sculpted surfaces of the original pulpit [7]. The photogrammetric model obtained by applying the Structure from Motion (SfM) methodology was appropriately scaled, based on homologous points, to the point cloud generated by the laser scanner application. The resulting orthometric unfolding on the plane of the seven circular crown tiles allowed for the representation of all elements in true size. This output becomes significant for a global vision of the system, as it allows each element or portion of it to be analyzed in relation to the others, understanding certain phenomena (e.g. compositional logic, chromatic choices, narrative decisions, but also aspects related to the monitoring and conservation of surfaces) not easily analyzed through a partial vision.

From the general orthomosaic, the images of the two panels III and IV were selected and optimized to produce a high-resolution for reproduction on a 1:1 scale. Once printed, this work replaced the two tiles removed from the plinth, producing a visual chromatic continuity with the original pulpit. (Fig. 3).

To enhance the three-dimensional component of Donatello's artwork, a detailed 3D model of the entire pulpit was produced with range-based tools, from which portions of the same panels were extrapolated, optimized, and processed to be prepared for 3D prototyping.

4 Reverse Modeling Processes for 3D Prototyping

In the field of cultural heritage, 3D printing finds its most specific application in museums and museum collections: here, the touch-accessible reproduction of sculptures, bas-reliefs, artifacts, mosaics, etc., drives the user into a new and in-depth type of knowledge [8]. The digital reconstruction process, developed from the use of laser scanners and photogrammetric technologies, enables non-invasive heritage analysis. When this process is realized in prototyping and 3D printing, it offers the advantage of reliable, lightweight, manageable, and reproducible copies. By working with these technologies, it is possible to model and produce copies at different dimensional scales while maintaining the correct proportions and textures of the material component [9]. The study of the digital duplicate of Donatello's pulpit was an opportunity to experiment with 3D printing to offer a more attractive tour. The two tiles were digitized and prototyped for 3D printing, enabling a new type of fruition, visual but above all tactile, of the sculptural work [10].

Fig. 3 Photogrammetric acquisition methodology and orthomosaic process for the positioning of the final photoplan on the pulpit **a**, that can be substitute with 3D printing **b** (Editing: C. Rivellino)

Starting with range-based instruments acquisition (Artec Eva, a structured light 3D scanner for small and medium-sized objects), a 3D database—consisting of 75 scans—was produced. Even though the prototyping process covered about 30% of the acquired data (2 out of 7 tiles), it was essential to generate a single complete 3D system of the pulpit to ensure proper alignment of the scans (Figs. 4 and 5).

The post-production phases followed two different software packages. The data acquired by the Artec Eva instrument are managed and processed using Artec Studio Pro software developed by the same manufacturer. After import, each scan must be optimized through the registration command. In this way, a process of aligning the individual clouds within the scan is carried out, to reduce errors caused during the data acquisition phase. This is followed by the scan alignment phase, which is carried out by identifying homologous points between adjacent scans. Once the scans are aligned, a reverse modeling process takes place whereby a single mesh surface is

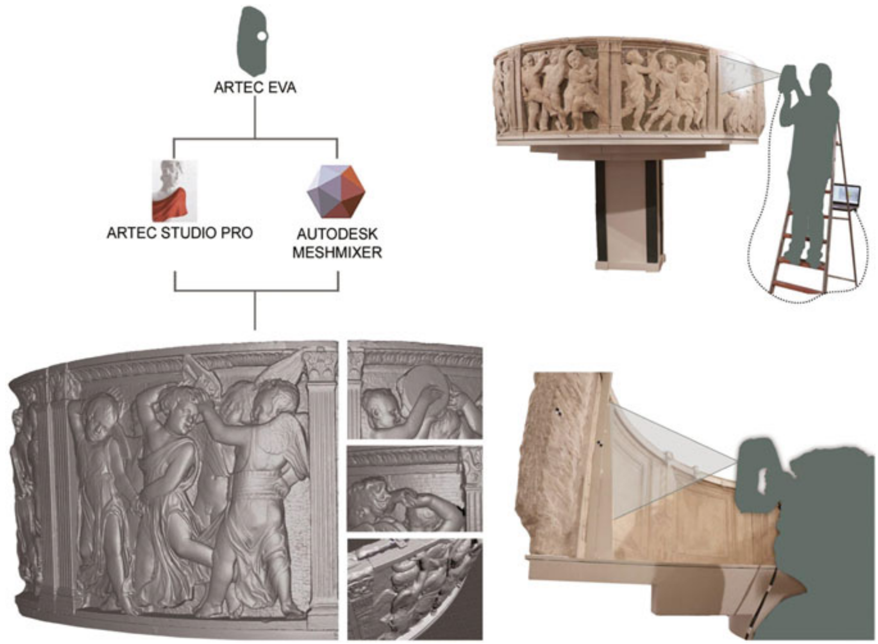

Fig. 4 Laser scanner data acquisition methodology (Modelling: H. Fu and C. Rivellino)

generated. The resulting mesh model of the two tiles (consisting of a triangular mesh of 58,820,300 polygons) was exported in.obj format.

With this amount of geometric information, it is possible to produce a model down to a scale of 5:1. For this reason, a significant decimation of the mesh was planned, reducing it by 50% (29,418,650 polygons). A second part of the model post-production phase takes place within the Autodesk Meshmixer software. This is where operations enabling optimization are carried out: removal of features caused by noise, removal of holes, reconstruction of small missing portions, etc., aimed at obtaining a closed solid model (manifold) (Fig. 6).

A number of 10 3D printers (Creality ender-5 Plus model)—part of the DAda-LAB and PLAY laboratories equipment—were used for the physical prototyping of the model. These are equipped with a 35 × 35 cm print bed and are among the largest desktop FDM 3D printers on the market. The maximum printable pattern size depends on the printing plate. It is—therefore—necessary to divide any model into several blocks of maximum 35 cm per side.

For the reproduction of 1:1 scale copy, a total of 18 blocks—9 for each tile—were provided.

Once the individual blocks have been set, the models are emptied to optimize printing time and costs. This procedure involves generating an offset surface, with the normal oriented towards the center of the block, thus transforming a solid into

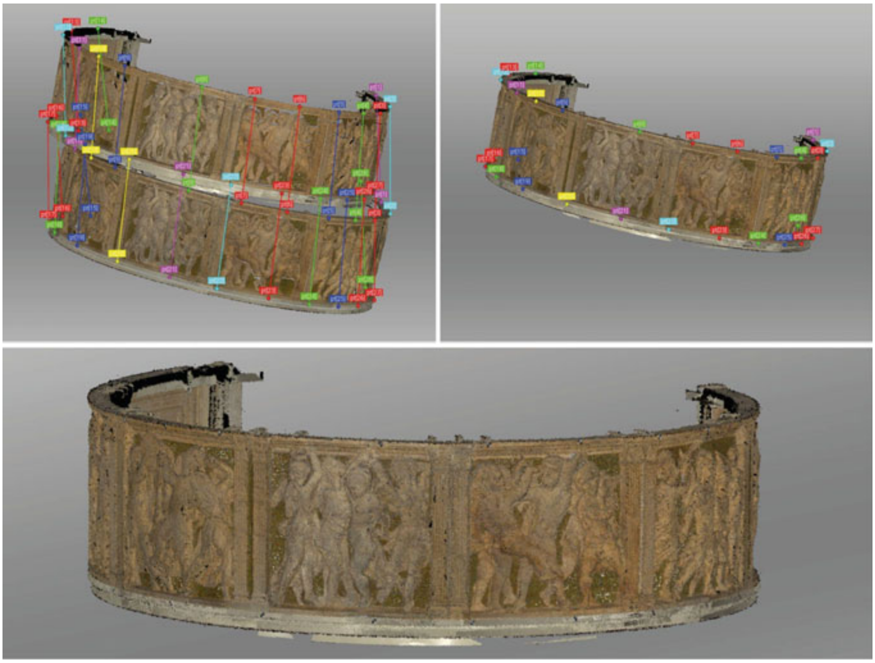

Fig. 5 Data alignment between scans considering target (Modelling: H. Fu)

a shell—without changing its external appearance—but reducing the filler material by around 60% (Fig. 7).

The shell thickness is determined by the set offset value (7 mm in this case), followed by different validation tests. To avoid any possible twisting or deformation, an internal reinforcement was inserted, a square-based joist connecting opposite surface walls. Finally, to avoid the automatic generation of the internal support, the upper wall was inclined by 15°. The optimized mesh model was exported in.obj format to be loaded into the 3D print management software (Cura Slicer). Codes were generated in.gcode format, and contains all the commands relating to the printing process (extruder position and speed, amount of filament injected, temperature of the print bed and nozzle).

Once the printing was finished, the automatically produced supports for the embossed parts were removed. The surfaces were cleaned of any imperfections due to residual material produced by the extruder. Finally, some surfaces were filed and grouted—removing any imperfections caused by the printing error—and then the parts were glued together (Fig. 8).

The use of white PLA filament, which makes the prints of the two tiles monochromatic, was a specific communicative choice. On a visual level, the objective was to emphasize the stiacciato technique, as the homogeneity of the color highlights the shadows and thus the depth of the bas-relief [11]. At a tactile level, it was planned

Fig. 6 Optimization procedures for features removal (e.g. noise, holes, reconstruction of small missing portions, etc.) (Modelling: H. Fu and C. Rivellino)

not to alter the height differences returned by the printer, which would have compromised the perception of roughness surfaces with even the slightest thickness. Furthermore, 3D prints can be made from materials that are more resistant to environmental conditions than traditional materials, making them more durable against changes in temperature or weather and thus increasing the longevity of artifacts [12] (Fig. 9).

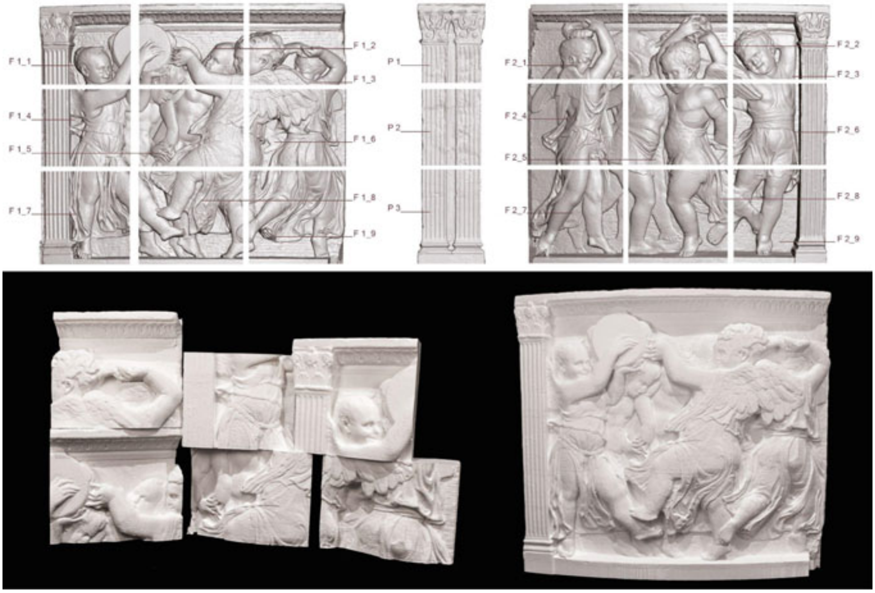

Fig. 7 Model segmentation in nine portions for each tile (Editing: C. Rivellino, photos: F. Picchio)

Fig. 8 The 3D printing process and the removal of any imperfection from the printed surface (Photos: F. Picchio)

Fig. 9 General image of the 1:1 scale 3D printing of the tiles. Below, detail of the surface roughness for the touch fruition (Photos: F. Picchio)

5 From Tactile Fruition to AR Applications

The 3D-printed model of the two tiles was displayed in the Museum's Sala del pulpito, with the possibility of being positioned in two different places in the room. An initial display was designed to insert the two printed panels in place of the two removed panels, creating a geometric continuity with the remaining panels of the pulpit but visually contrasting the uniform white coloring. However, the elevated position on the pedestal, although designed for direct real-digital viewing, does not allow tactile accessibility of all its parts. For this reason, a second fruition mode of the artwork has also been provided, to be used at the choice of the Museum's curators: the two printed panels are placed on a lower plinth, next to the original pulpit, to make them fully accessible. In the portion of the missing pulpit panels, the high-definition orthophoto of the two removed tiles has been inserted. This fact, in addition to facilitating the touch ability of the digitized and printed copy, also makes it easier to develop digital AR and VR applications to increase museum audience development [13]. In this way, it will be possible to enrich the visiting experience and spread knowledge of the work to a wider public [14].

A first Augmented Reality application of the interpretive mediation type was planned to restore the color component to the two PLA tiles: by using a smartphone and scanning a QR code in the proximity of the printed model, it is possible to virtually match the colorimetric information of the original tiles to the monochrome model. What appears on the display is a textured digital model of the two removed tiles, which aligns and overlaps with the 3D printed model. The communicative intention, in this case, was to achieve a visual effect that is anything but obvious: it is the user himself who, by choosing what to frame, gets to know the work through the discovery of certain specific chromatic aspects of the marble or polychrome tiles. The partial view of portions of textures, made possible by the AR application, prompts the observer to focus attention on details that are often missed in an overall view.

The alignment between the two models (the real monochrome printed one and the textured digital one) is ensured by the software developed. This automatically traces the image of the printed real model and, depending on the position and movement of the visitor, the application installed on the mobile device is able to dynamically correct the position of the digital model in real-time in relation to the static model positioned in space (Fig. 10).

The application for AR visualization of the textured component of Donatello's pulpit was developed using Unreal Engine 4 software, and prepared in apk format for Android devices. The function is activated via a QR code placed in the physical space or a touch button placed on the display of the mobile device. After the input signal, the model is loaded and automatically shown on the display [15].

A second application, of the type Outdoor guides and explorers, provided for the accessibility of the model outside the museum walls. Using the Sketchfab platform, it is possible to use the full-scale model (1:1) from one's mobile device within any space in which the user is located, via a link and in markerless mode. The activation of the AR function is followed by a time (about ten seconds) for the recognition of

Fig. 10 Augmented reality on-site and hall museum exposition with different digital outputs (Photos: H. Fu and F. Picchio)

the physical space and to establish a support plane on which the model is virtually placed. Once viewed, the user can move around the 3D model of the two tiles or freely approach them with a smartphone to enjoy the sculptural artwork from each angle (Fig. 11).

An advantage of augmented reality in such contexts is that it can provide augmented information at any point of a hypothetical museum tour or route, as well as in the comfort of one's own home or in places dedicated to education, thus promoting visitor learning in a more entertaining way (edutainment).

In this sense, augmented reality, as well as virtual reality, can play a relevant role from many points of view in heritage valorization and education, as they foster knowledge, re-elaboration and participation [16].

Not only the scenarios—real or virtual—in which the user is surrounded, allow the artwork to go beyond the physical limit of tangible matter. It is above all with the evolution of the museum user, who is no longer a mere spectator—in terms of perceptual mode and fruition sensitivity [17]—that the digitized artwork itself acquires new meanings and modes of interaction. In the user—artwork interaction, it can also be the user himself who configures his visit and which elements to interact with, as in the case of digital scenario reconstructions for serious games from accurate reproductions of the works [18]. In this sense, the contents of a artwork are constantly renewed, generating new forms of communication and allowing digital reproduction to change, preserving itself over time and becoming a artwork with its own identity.

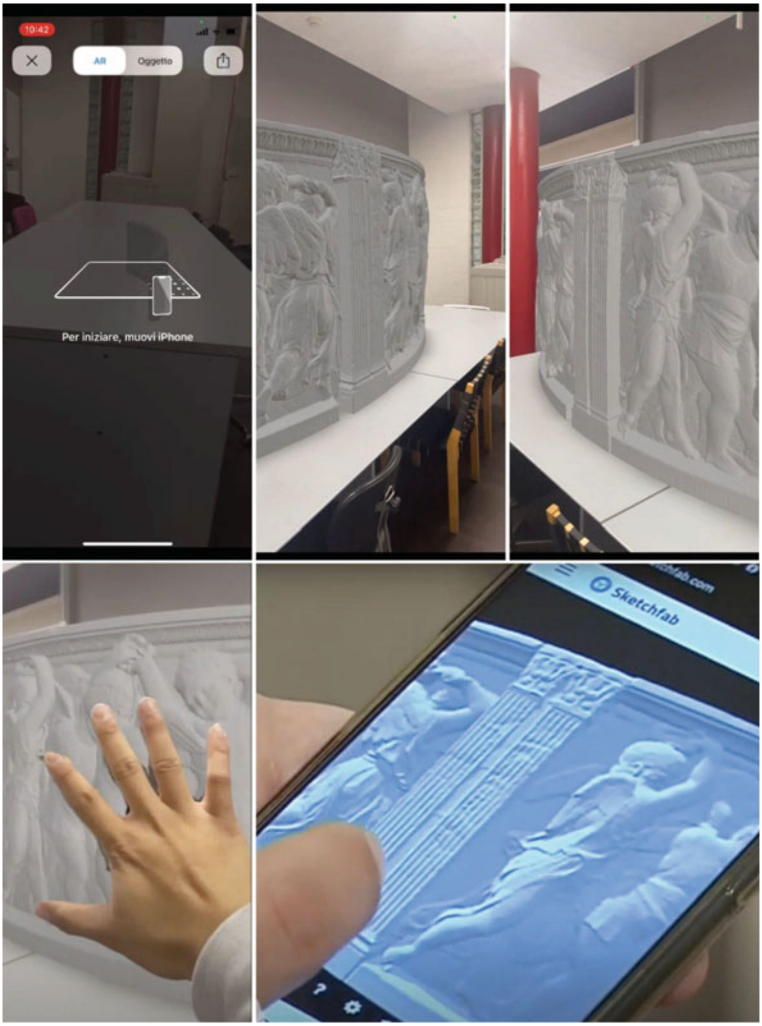

Fig. 11 Augmented reality for outdoor guides and explorers, using a device from which it can be uploaded a sketchfab model (Modelling: H. Fu, photos: H. Fu)

6 Conclusions

The relationship between digital technologies and museums, which has grown exponentially over the past decades, is now a phenomenon that current exhibition routes are unlikely to renounce. From websites to mobile apps, from touch installations to 3D printing, to augmented and virtual reality applications, the exhibition route is transformed by fully integrating technologies into the museum system, establishing a crucial shift from exhibition to heritage education.

Any operator can successfully reproduce the features of an artwork in a virtual duplicate that can be experienced by an electronic device. In addition to the faithful geometric reproduction of the model, a requirement that any duplicate must certainly possess, the technological museum layout aims to offer the visitor something more of the content and values of the artwork itself. In order for the work and the digital exhibition of which it is a part to communicate these values, it is necessary to effectively develop a specific and unambiguous museum narrative (a storytelling) [19]. This must involve the public to become an active part of an exhibition itinerary, so that each user can build his or her own visit path to know the artwork [20].

The exhibition proposal conceived for the pulpit room in the Museo dell'Opera del Duomo in Prato aimed at structuring a path of knowledge of the morphological and chromatic components of the pulpit panels, which could also be experienced through the use of digital tools and products. For this reason, different types of digital products and access to them have been envisaged. On the one hand, the touch reproduction of 3D printing makes them suitable for various educational purposes and attractive, interactive and inclusive forms of musealization [21, 22].

The copies realized become new representative models, which interpret the original work and increase its accessibility and knowledge, structuring an innovative narrative and exhibition route. Using augmented reality applications, an approach was undertaken to recreate the feeling of the presence of the two removed tiles, as if they were actually present and integrated into the real world, either in the room from which they were taken, or in an external environment, to be conveniently viewed at a time and manner chosen by the user.

In order to illustrate the digitization process undertaken and to encourage visitors to use the digital products on display, the exhibition design was accompanied by several information panels and a video trailer, designed and produced to describe the entire methodological process undertaken by the digitisation project (Fig. 12). The temporary exhibition the digital documentation of Donatello's pulpit, a journey of knowledge between Art, Architecture and Faith opened on 11 June 2022 in the pulpit room of the Museo dell'Opera del Duomo.

In the temporary installation project, the original pulpit work remains in the center of the room, while part of it houses the panels, video and 3D print. The intention was to integrate the new products into the environment and not make them perceived as disconnected or disturbing elements in relation to the original work. The basic idea is that technology can enhance its communicative aspect and user-friendly interface [23], without constituting—in any case—a cognitive, physical or economic barrier for the end user and the artwork, whether original or digital copy.

Fig. 12 Main informative panels that describe the digital research and the obtained products (Editing: F. Picchio and H. Fu)

Acknowledgements The documentation activities of Donatello's pulpit, promoted by the Director of the Museo dell'Opera del Duomo di Prato and the Ufficio Beni Culturali Musei Diocesani, in synergy between the University of Pavia and the University of Florence, and thanks to the funding of the Fondazione Cassa di Risparmio di Prato. Coordinating the research activities, which lasted almost a year and were directed by Professor Stefano Bertocci of the University of Florence, were Dr. Marco Ricciarini of the University of Florence and Dr. Francesca Picchio of the University of Pavia. A working group of PhD students, young researchers and students from the two universities was involved in the realization of the different digital products for the exhibition.

References

1. Parrinello, S., Picchio, F., La Placa, S.: Understanding, interpreting, and shaping a dialogue between drawing and digital modeling. The case study of Donatello's pulpit. In: Varum, H., Furtado, A., Melo, J., (eds.) ReUSO—Documentation, Restoration and Reuse of Heritage—Porto, Portugal, vol. X, pp. 103–114. e-book (2022)
2. Ippoliti, E., Albisinni, P.: Virtual museums. communication and/is representation. Disegnarecon **9**(17), 1–15 (2016)
3. Parrinello, S., Dell'Amico, A.: Experience of documentation for the accessibility of widespread cultural heritage. Heritage **2**(1), 1032–1044 (2019)
4. Dello Russo, M.: Storia della Sacra Cintola di Prato, Stamperia Ferrante, Naples (1858)
5. Giusti, A., Biliotti, C.: ... sì belli e sì mirabili: recuperi e limiti nel restauro dei rilievi donatelliani. In: Giusti, A. (ed.) Donatello restaurato. I marmi del pulpito di Prato. Maschietto Editore, Florence, pp. 61–72 (2000)

6. Rivellino, C., Ricciarni, M.: Testing the reliability of mini-UAVs acquisition campaign on detailed bas-reliefs. The case study of sculpturing elements of Donatello's Pulpit. In: Barba, S., Parrinello, S., di Filippo, A., Dell'Amico, A. (eds.) D-SITE—Drones Systems of Information on Cultural Heritage for a Spatial and Social Investigation, pp. 518–526. Pavia University Press, Pavia (2022)
7. La Placa, S., Parrinello, S.: Vectorialization practices of the image drawing of the floor mosaics of the Basilica of Nativity in Bethlehem. SCIRES-IT-Sci. Res. Inf. Technol. **9**(2), 95–104 (2019)
8. Hangjun, F.: Le stampe 3D per una fruizione tattile delle sepolture. In: Bruno, B., Napione, E., Picchio, F. (eds.) I Mondiali di Italia '90 e la scoperta della necropoli romana Un progetto espositivo per il trentennale della scoperta della necropoli di Porta Palio, pp. 99–105. Pavia University Press, Pavia (2022)
9. Lo Turco, M., Calvano, M., Giovannini, E.C.: Data modeling for museum collections. Int. Arch. Photogrammetry, Remote Sens. Spat. Inf. Sci. **42**(2/W9), 433–440 (2019)
10. Neumüller, M., Reichinger, A., Rist, F., Kern, C.: 3D printing for cultural heritage: preservation, accessibility, research and education. Lect. Notes Comput. Sci. **8355**, 119–134 (2014)
11. Bitelli, G., Girelli, V.A., Medica, M., Tini, M.A.: From 3D surveying to replica, a resource for the valorisation of museum artifacts. The case of the bas-relief of Giovanni da Legnano in Bologna. J. Phys.: Conf. Ser. **2204**, 012093 (2022)
12. Tissen, L.N.M.: 3D printing and the art world: current developments and future perspectives. In: Sharma, A. (ed.) Advances in 3D Printing, on-line (2023)
13. Carci, G., Caforio, A., Gamper, C.: Tecnologie digitali nei musei: realtà aumentata, apprendimento e audience development. Form@re—Open J. per la formazione in rete. **19**(1), 274–286 (2019). Firenze University Press
14. Russo, M.: AR in the architecture domain: state of the art. Appl. Sci. **11**(15), 6800 (2021)
15. Palma, V., Spallone, R., Vitali, M.: Augmented Turin baroque Atria: AR experiences for enhancing cultural heritage. Int. Arch. Photogrammetry, Remote Sens. Spat. Inf. Sci. 557–564 (2019)
16. Panciroli, C., Macauda, A.: Educazione al patrimonio e realtà aumentata: quali prospettive. In: Giornale Italiano della Ricerca Educativa. anno XI, numero 20. © Pensa MultiMedia Editore srl. on-line (2018)
17. Giordano, A.: New interoperable tools to communicate knowledge of historic cities and their preservation and innovation. In: Luigini, A. (ed.) Proceedings of the 1st International and Interdisciplinary Conference on Digital Environments for Education, Arts and Heritage. EARTH 2018. Advances in Intelligent Systems and Computing, vol. 919, pp. 34–43. Springer, Cham (2019)
18. Parrinello, S., Miceli, A., Galasso, F.: From digital survey to serious game. A process of knowledge for the Ark of Mastino II. DisegnareCon **14**(27), 17.1–17.22 (2021)
19. Bonacini, E., Tanasi, D., Trapani, P.: Participatory storytelling, 3D digital imaging and museum studies: a case study from Sicily. In: 2018 3rd Digital Heritage International Congress (DigitalHERITAGE) Held Jointly with 2018 24th International Conference on Virtual Systems & Multimedia, pp. 1–4 (2018)
20. Parrinello, S., Dell'Amico, A., Galasso, F.: Arsinoe 3D. La narrazione digitale di uno scavo archeologico Scenari digitali: la digitalizzazione dello scavo di Arsinoe. 43° Convegno Internazionale dei Docenti delle Discipline della Rappresentazione Congresso della Unione Italiana per il Disegno—Atti 2022, pp. 881–902 (2022)
21. Balletti, C., Ballarin, M.: An application of integrated 3D technologies for replicas in cultural heritage. ISPRS Int. J. Geo Inf. **8**(285), 1–29 (2019)
22. Scopigno, R., Cignoni, P., Pietroni, N., Callieri, M., Dellepiane, M.: Digital fabrication techniques for cultural heritage: a survey. Comput. Graph. Forum **36**(1), 6–21 (Jan, 2017)
23. Bonacini, E.: La realtà aumentata e le app culturali in Italia: storie da un matrimonio in mobilità/ Augmented reality and cultural apps in Italy: stories on a marriage in mobility. Il capitale culturale. Stud Value Cult Heritage (9), 89–121 (2014)