Augmented Visual Models of Scientific Zoological Collections. A User Experience at the MUSA University Museum

Pierpaolo D'Agostino, Giuseppe Antuono, Pedro Vindrola

Abstract

The present work wants to configure itself as a paradigmatic contribution proposing a methodological approach for an augmented fruition of museums and their exhibits. Currently heritage, museums and the way of experiencing them are undergoing a paradigm shift, due to all the digitalization era, where it has to overcome this transition and take advantage of it, capitalizing on what these new technologies have to offer.
An augmented fruition experience of a study case is proposed, where the augmented component is configured by combining state-of-the-art techniques with traditional ones. Where rapid prototyping, different survey techniques and augmented reality in fusion with the standard ways of showcasing objects are used, in the museum center of agricultural sciences (MUSA) of the University of Naples Federico II in Portici. The augmented fruition for all heritage of the museum is the outcome of a three-way relation made between the new technologies and the two key concepts: preservation and divulgation. Where the technologies offer ways to develop strategies, more efficiently, for divulgation and preservation; and the second two facilitate a field of application for pushing the limit of these technologies further and further.

Keywords: scientific collections, cultural heritage, extended realities, rapid prototyping, virtual fruition model.

Introduction

Drawing and design –as tool a of representation– have been in the past the main tool for the manifestation of ideas; today, in the 21st century, the discipline of representation is in the situation of having , with flexibility and adaptation, todeal with rapid technological changes, reinventing and experimenting with new digital environments of communication and fruition.
Communication, as a disciplinary field, since the World Wide Web advent [Huhtamo 2010, pp. 121-135], that led to the rapid growth of web applications in the 1990s [Hooper-Greenhill 2003, pp. 1-40; Oppitz, Tomsu 2018, pp. 201-227], has undergone a migration from the analog to the digital realm, developing new languages (hypermedia, augmented reality, virtual content) that finds fertile ground in the cultural heritage sector, with particular reference to the Digital Transformation of art and museums [Bertacchini, Morando 2013, p. 62; Bolognesi, Aiello 2020, pp. 83-90], enabling innovative modes of fruition [D'Agostino, Antuono, Elefante 2022, pp. 399-407]. The museum and art sector had to assimilate with struggle these new technologies [Parry 2010, pp. 1-8] and this sector "re-formulation process" [Cameron 2010, pp. 80-95] continues, since they are, in many situations, already the main channel of access to information about cultural heritage; new forms of democratization of culture have been made possible by the revolution set in motion by the World Wide Web which, representing a rupture from the past,

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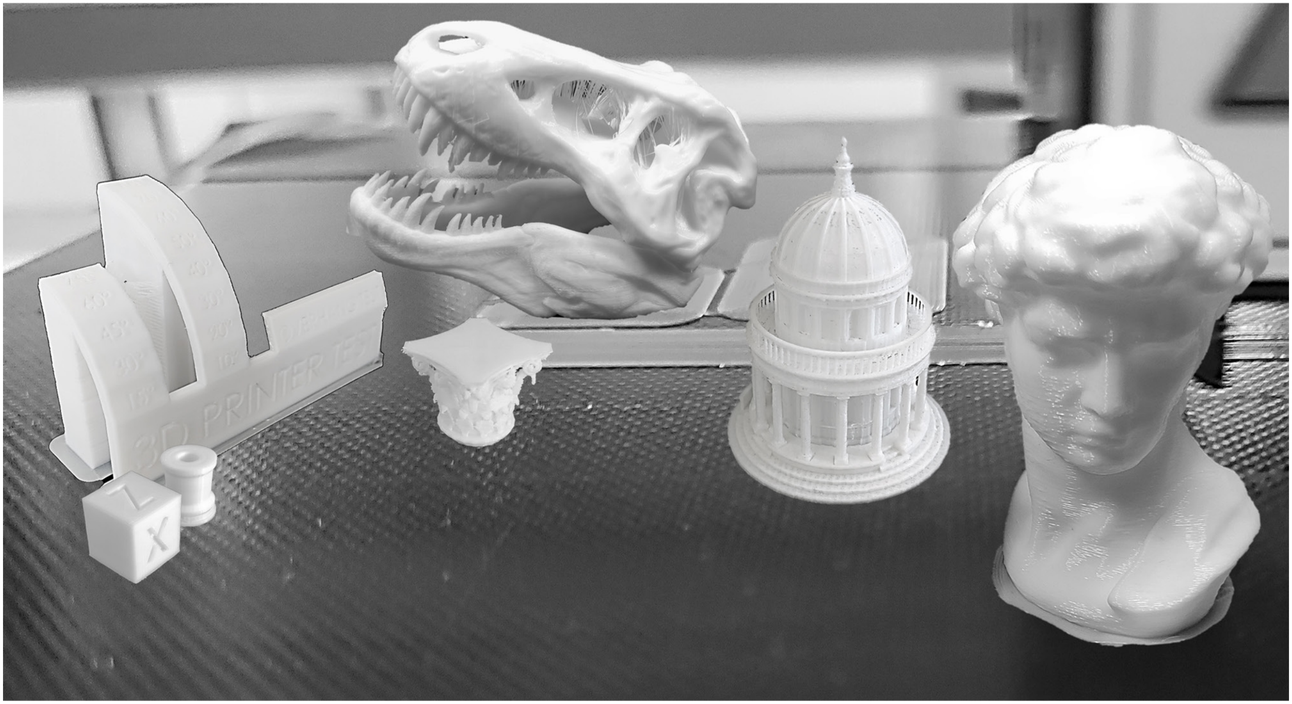
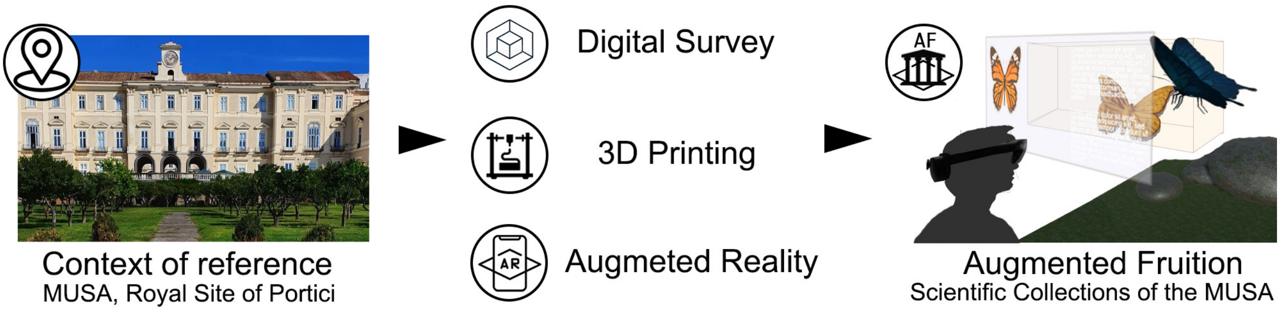
Fig. 1. In-house prototypes for experiments between real and virtual elements of museum heritage (authors' elaboration).



has changed not only the creation and distribution of information but, also multiplied the opportunities for exchange, accessibility and participation of the user; who is called to interact in pervasive and cross-media digital environments.
Currently, heritage, museums and the way they are experienced are undergoing a paradigm shift, due to the whole era of digitization, which must overcome this transition and leverage it, capitalizing on what these new technologies have to offer. In this perspective, moreover, after an initial establishment of digital surveying techniques, such as laser scanning and photogrammetry, recent years have witnessed a paradigm shift in digital fruition, with the reconstruction of material prototypes (fig. 1) and increasingly related to words such as metaverse, Extended-Realities (xR), etc., which are beginning to appear in the glossary of an audience –not only in 'native' digital sciences– increasingly more at ease with the technologies, as well as feeling familiar with these neologisms [Sherman, Craig 2018; Huggett 2020, pp. 1-15; Allam 2022, pp. 771-801].
Now with the global situation related to the pandemic [Cicerchia, Solima 2020, pp. 1-27], information and communication technologies for augmented reality (AR) and virtual reality (VR), have enabled the user to simultaneously interact with the real and virtual environment, enhancing experiences and conveying the content of the cultural product in order to facilitate connection, especially to remote access [Kang, Yang 2020, pp. 139-161], and have a deeper understanding of it. Hence, the push today is toward greater complementarity of visual design technologies for digital innovation of museum



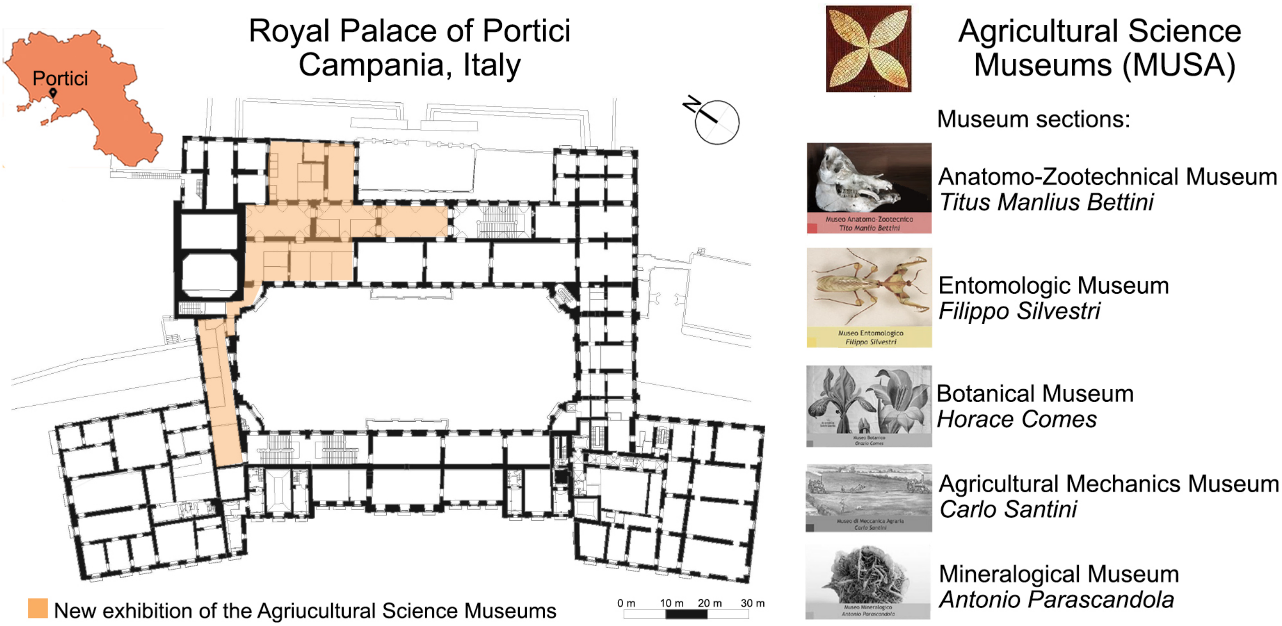


Fig. 2. Methodological workflow: from the context of MUSA in the Royal Site of Portici to artifact augmented-fruition of the scientific collections (authors' elaboration).

Fig. 3. Framing of the site: the whole exhibition area of MUSA's scientific collections on the main floor of the Royal Site of Portici (authors' elaboration).

knowledge pathways, in line with the new International Council of Museums (ICOM) definition of a museum, which focuses specifically on "providing diverse experiences for education, enjoyment, reflection and knowledge sharing." The goal is to be able to make artworks 'express' works of art in innovative ways, through devices and interfaces, while also aiming to integrate tactile modes of interaction with multisensory experiences into communication [Neumüller et al. 2014, pp. 119-134; Khunti 2018, pp. 1-12].
To this end, the present contribution, in discernment of new digital languages (fig. 2), proposes an organic method of informative correlation in the virtual fruition of artifacts in a museum space, experimenting –in particular– in the Museum Center Museums of Agricultural Sciences (MUSA), combining, from data acquisition through digital sensing technologies, to augmented fruition techniques and rapid prototyping in accordance with the standard ways of exhibiting collections, in the recently restored rooms on the main floor of the Palace of Portici (fig. 3).

From real to virtual and back. A method exemplification

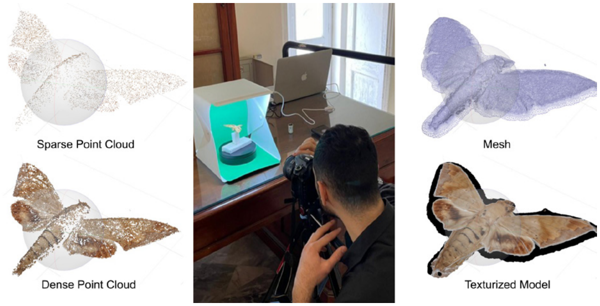
In line with the three criteria for efficient cultural dissemination (quality, quantity, and accessibility of content), the basis of *audience development strategies* –understood as a useful tool for understanding the opportunities arising from digital media with the goal of enhancing the lived experience of the public, by proposing new and appropriate ways so Cultural Heritage can be enjoyed and fruited by the community [Ippoliti, Albisinni 2016, p. E6] –and *audience engagement*– consecutive in creating a context of interaction, participation, and experience that leads to engagement, audience satisfaction, and all this to the construction of a sense of identity [Ippoliti, Albisinni 2016, p. E4]–, this proposal describes a pilot of XR technologies in integration with rapid prototyping for the preservation and dissemination of the numerous exhibits of the significant heritage of scientific collections, regarding the entomology and zoology sections of the MUSA in the Palace of Portici.
The opportunity to set up and open to the public the new exhibition spaces on the main floor by the end of the year 2022, as well as the recognized fragility and high-risk condition in the exhibition of artifacts, allowed to define a framework of activities to implement the virtual in the real space of the museum site, in line with the demands of the National Recovery and Resilience Plan (PNRR) –implementing tangible and intangible infrastructure of the historical and artistic heritage through digital investments–, with the goals of Agenda 2030 –in improving accessibility to information as well as the quality of education through information and communication technologies– and with what has been stated internationally with the UNESCO Recommendation from 2015 [UNESCO 2015] – which promotes the protection of cultural heritage. Thus, to enable easier and more immediate sharing of content, thanks to the digitization of collections and consequently better preservation of heritage, and thereby reach a wider and more diverse audience a new exhibition paradigm was tested. The experimentation was carried out by using the transparent screens of a Liquid Crystal Display (LCD) to conform a digital showcase in the integration of AR devices. The objective is to implement a visitor's fruitive experience with the environment and scientific collections, to enhance and implement the interaction between information content and the material-virtual container, intensifying the integral experience of the museum object, through multiple senses, in the reflection on the product-space-use relationship for the future use of the museum halls, which are undergoing restoration work.
The exhibits examined in this research refer to different types of animal and multiscale species, preserved today in inaccessible places because they are subject to the risk of environmental deterioration; the size of the objects, their different types and, above all, their belonging to different disciplinary fields determined a particular complexity of investigation that has seen the experimentation and evaluation of different techniques of digital data detection and integration, useful for reconstructing their related geometric-material models in the augmented reality information component.
Therefore, the methodological workflow applied to the experimental site (figs. 2, 3) included the stages of:
- Digital survey of the museum artifacts and integration of the acquired data of the museum space;
- Digitization and modelling of the museum holdings;
- Rapid prototyping with production testing of museum artifacts;
- Creation of a digital display case and fruition in AR.

Fig. 4. Survey stages of the Systems-Sense 2 3D laser triangulator scanner and the digital reconstruction of the mammal Mustela nivalis of the family Mustelidae, part of MUSA's zoological collection (authors' elaboration).

The stages enclose and conclude with the fulfillment of the goal of achieving augmented fruition of the collections within the museum space.

From survey to prototype of scientific collection exhibits

In recent years, foundations, museums, and in general all institutions, which are committed to enhancing the value of historical collections and preserving their value beyond the destructive action of time, have realized the potential of using digitalization approaches. Because make it possible to archive and reproduce the geometric characteristics of historical works, without compromising the integrity of the collections, describing new paths of virtual visitation and allow the visualization and re-imagining of historical spaces and objects that would generally be left to the imagination of visitors [Empler 2018, p. 13.10].
In line with new developments, for the study and acquisition of 3D models of the Museum of Agricultural Sciences architectural and collecting heritage, various digital survey methodologies were used to describe the museum room spaces and to reproduce the various objects, with different sizes and typologies, useful for testing the feasibility of the techniques for the proposed objectives.
The first macrophase involved the digital laser scanner survey of the different rooms of the new museum rooms on the main floor of the Reggia, using a Leica BLK 360, returning an integrated model useful for the space-conform reading of the access and passage paths, as well as the relationships with the natural lighting systems.
In a second macrophase, the findings were acquired at two different times, using two different digital sensing techniques. The first one involved acquisition based on triangulation scanning system. Specifically, a 3D Systems-Sense 2 was used, equipped with two cameras, one for image acquisition, the other equipped with a depth sensor, which, based on geometric triangulation criteria, allow the reconstruction of an unstructured point cloud model in real time. The result is a detailed model in texture reproducibility –was also tested for the other types of artifacts taken from the museum– described by a surface of polygons, in the *Mesh Re-*



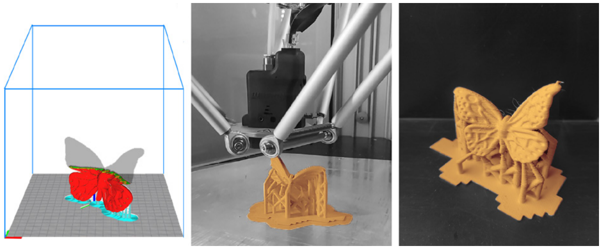
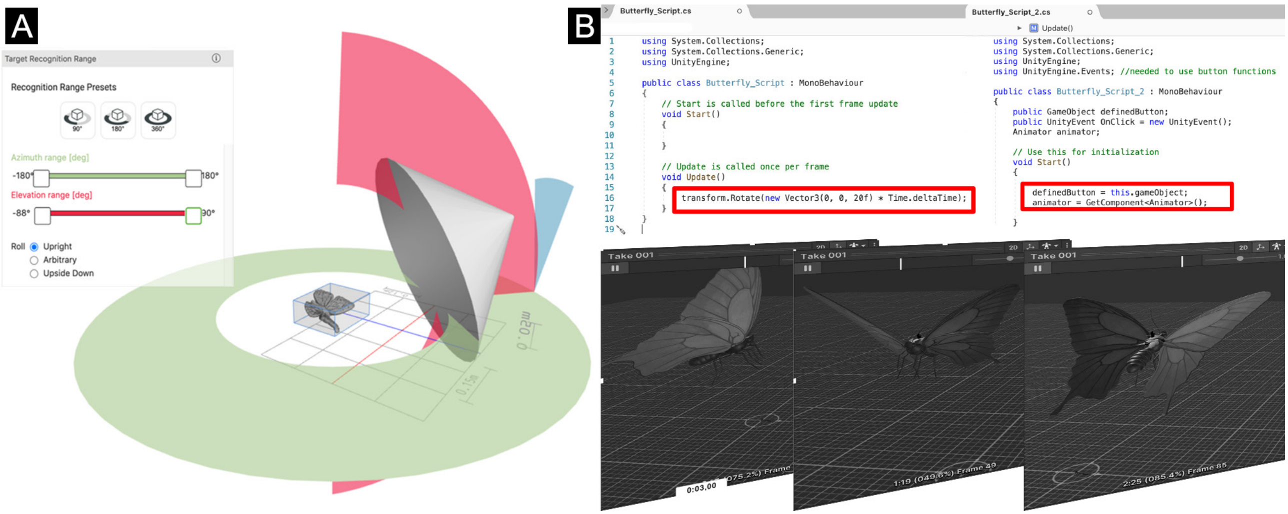


Fig. 5. Photogrammetric survey and digital reconstruction of an insect of the order Lepidoptera, part of MUSA's entomological collection (authors' elaboration).

Fig. 6. Lepidoptera prototyping process. From left to right: model setting and printing parameters; prototyping with Delta WASP 4070 type printer; one of the outcomes of the printing steps (authors' elaboration).

Fig. 7. Building the digital fruition model in AR mode: A) definition phase of the model Target; B) definition of the script in C# in Visual Studio for iterating and animating the model frames (authors' elaboration).



construction stage, textured through photogrammetric image mapping. Despite the execution of an image calibration procedure, the final model was found to have low fidelity, with just an approximation of geometric shapes compared to the small scale of the object, characterized by a reflective material (fig. 4).
Therefore, to meet the requirement for the survey of small artifacts and overcome the difficulties encountered –in the need for accuracy of the fundamental data for their digital reconstruction– digital photogrammetry, which is based on Structure from motion (SfM) techniques, was used, allowing the free form of bodies to be restored [Liva 2021, p. 12]. In particular, a Nikon Corporation D90, with an AF-S Nikkor 50mm lens and light box size of 25x25x25 cm on a swivel base, and XP Pen Deco 02 graphics tablet was used for masking the acquired images, yielding a focus on the object with increased point acquisition (fig. 5).
For this purpose the software, open source, FormWare was used, which allowed the mesh to be repaired in .stl format for the next stage of model preparation and definition of rapid prototyping parameters in Ultimaker Cura (fig. 6). These included validating the mesh, identifying any missing parts and closing the surface in *Mesh Tools,* defining in *Cylindric Custom Support* the supports to the model for the post-production phase, or again verifying the parameters of correct positioning and adhesion of the object on the printing plane in *Auto-Orientation*.
After this phase was completed, the prototypes were printed through a Cartesian-type Anycubic I3 Mega S and a delta-type Wasp 4070 Pro in PLA bioplastic material (fig. 6). Also was tested the outcomes with respect to the achievement of the objective and the definition of the parameters that determine, for example, the retraction that is used to regulate the length of the same of the wire to avoid problems of stringing –as well as avoiding a warping problem related to adherence to the plate– and monitoring the printing temperature, aiming to avoid the problem, still present with this type of prototyping technology, of under-extrusion. Despite the performance of the Wasp 4070 Pro, which is indeed more oriented to the prototyping of medium-format models, the Anycubic I3 Mega S maintains high defining capabilities of a base model with lower economic commitment; ergo, this last was replicated also with the

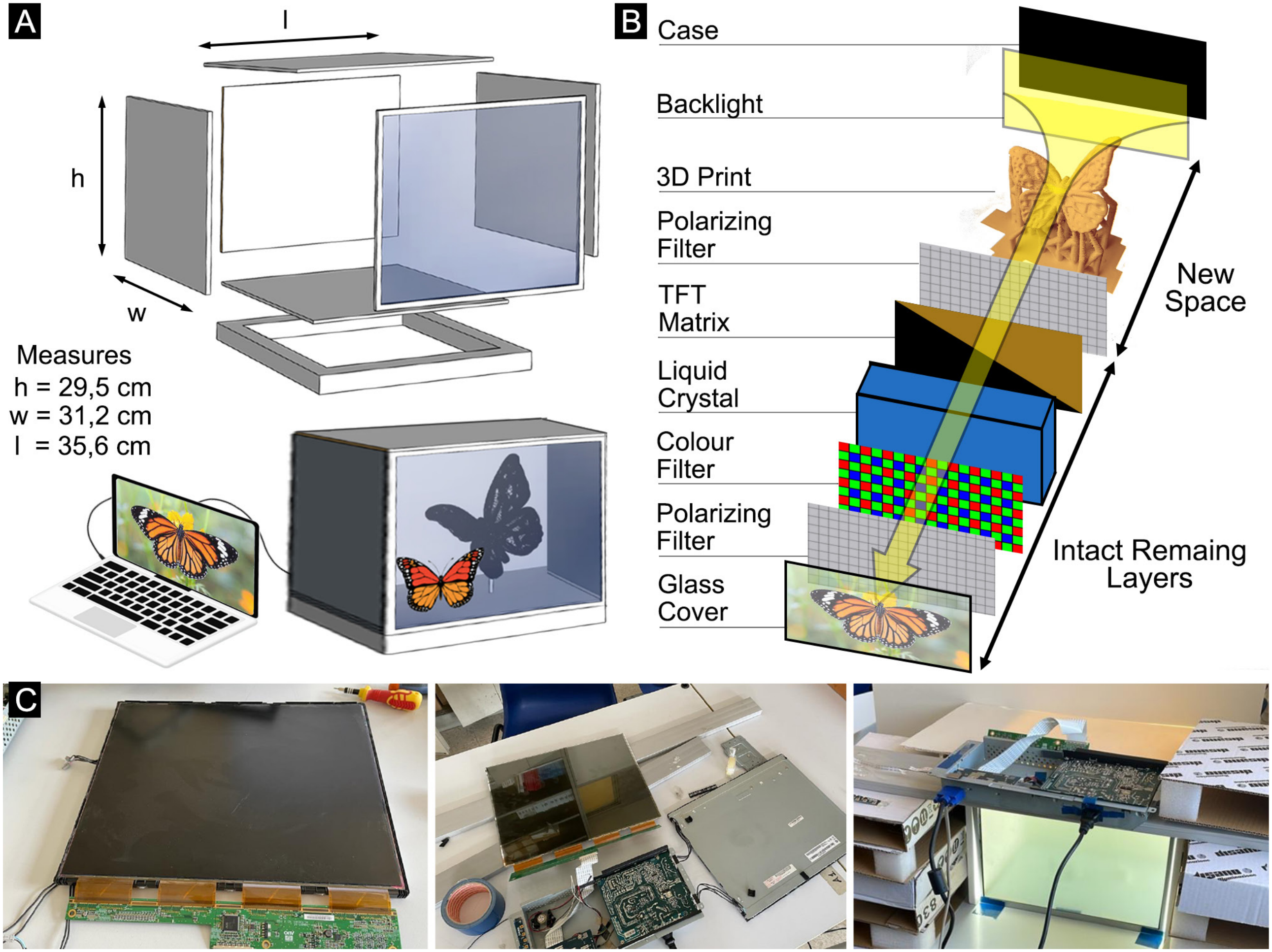
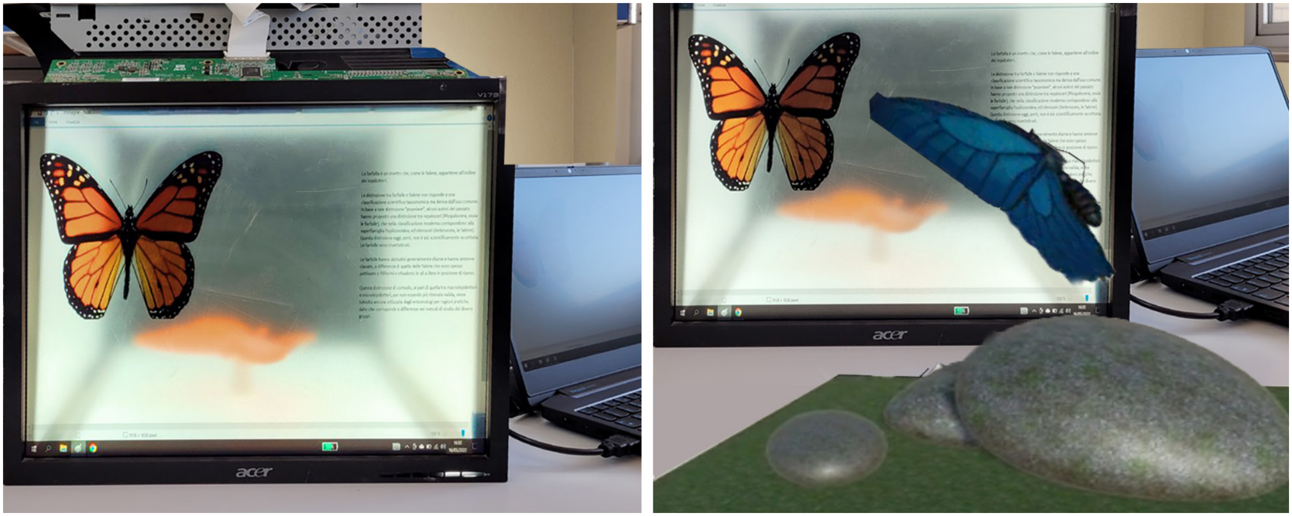


Fig. 8. Prototype development of multimedia display case with 4:3 LCD screen: A) drawing of the prototype; B) operation diagram; C) engineering stages (authors' elaboration).

Fig. 9. From left to right, prototype of the digital display case for information fruition and frame of the AR application (authors' elaboration).



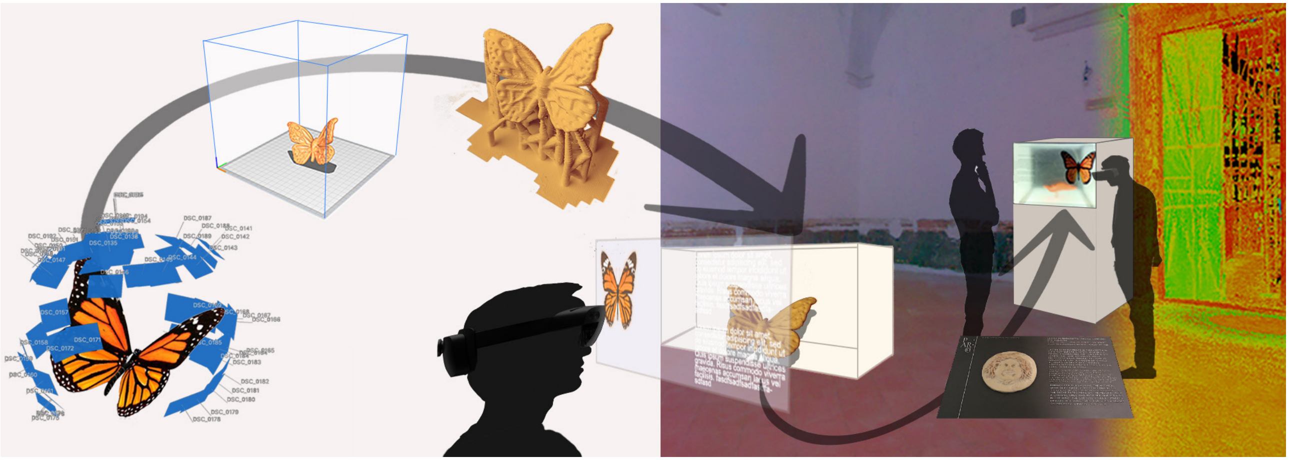
other elements of the MUSA's archive, for the preservation of authentic exhibits and, yet, more focus toward the possibility of a greater tactile performance of the model, which allows a more verisimilitude interactive experience with its reproduction [Ballarin, Balletti, Vernier 2018, pp. 55-62], as a rethinking of the visit path, by breaking down the barriers that ensured its preservation and integrating virtual information through augmented fruition technologies. The horizon that 3D printing of elements made interactive, eventually scalable, opens up allows in fruition not only informative sharing for the visually impaired, but also proposes a way to diversify edutainement, adding the sense of touch to the museum experience [Sdegno 2018, pp. 256-271].

Fruition of augmented visual models in a digital showcase

In accordance with the goals of expanding the informational experience to different categories of users of MUSA's scientific collections, the experimentation developed a digital prototype of integration between real and virtual [Papa, Antuono, Cerbone 2020, pp. 41-50], with the creation of a display case that, by expanding the traditional museum information systems (panels, audioguides, professional guides), allows the user to interact with the physic reproduction in scale of haptic models [Wilson et al. 2018, pp. 445-465]. In addition, it allows the user to deepen the digital resources of the associated digital objects in an immersive and augmented experience, useful for the preservation and dissemination of the collection heritage in the spaces of the museum's halls.
Therefore, from the digitization of the exhibits of the scientific collections, that can be loaded into the asset of the Unity multiplatform videogame engine, an AR application was developed, which synthesizes in the virtual scene the information associated with each element/exhibit. The project was configured for the Android operating system, using a predefined Unity template for 3D apps (fig. 7). Specifically, for the creation of the scene, AR graph-visual interaction modes were set up to recognize images and target models and, thus, enable interactivity with the real model in both the basic functions of motion tracking, i.e., understanding and

monitoring its position with respect to the world (identifying key points in the real environment and keeping track of how they move over time), and environmental understanding, to detect the size and position of the space and support augmented enjoyment, evaluating the current lighting conditions of the environment, optimizing the rendering of 3D objects. Hence, in structuring the digital content to support a museum fruition, the potential of a number of platforms were exploited, integrated inside Unity interface, capable of making the visitor interact with the prototype object displayed via device. In particular, Vuforia Engine, for the development of the augmented reality app and image target tracking of the virtual content in overlay with the dedicated museum space in direct dialogue with Unity. In addition, Visual Studio, for the creation of animation models associated with the model target, through the definition of a script in C# language, managed in model target generator that allows the model target tracking and the reconversion of 3D models in the online database Vuforia Developer Portal, which means recognizing, via device, the material prototype and launching the associated digital content.
To create the image targets, a number of photographs of the exhibits of the species chosen for experimentation were selected, subsequently uploaded to the Vuforia developer portal in order to make the image recognizable by the devices and imported into Unity. The next step was to associate the information content to be shown to users, with an image or video of the exhibit composition, as well as a brief description with shared scientific data related to the naturalistic collection.
At the same time, the virtual model of the artifact was finalized in the model target generator, which was then converted into the Vuforia Engine dataset, by defining the parameters of: model up vector, to establish the position and direction of the object; model units, to size the object and validate the correspondence between digital and physical object; complexity, to assess the degree of detail of the polygonal surface describing the digital model for easy enjoyment in mobile devices in real time (cell phones or AR viewers); model type, to typify the model as 3D Scan, i.e., created from photogrammetric textures; motion hint, to manage the type of object motion, in dynamic mode, during the recognition phase with AR device; Guide Views, as a support for object recognition and creation of different of views, either in overlaying the digital model to the physical model outline, or in 360° overview view for better immersive experience.

Fig. 10. Toward the design proposal: from the final fruition scheme to the set-up (authors' elaboration).



At this point it was possible to associate immersive digital content with the target model, pre-loaded in Unity, which involved interactions and animations of the object, structured and animated according to the creation of a specific script in C# language in Visual Studio. For the specific case under consideration of a volatile species, this allowed the object to fly and rotate to appreciate its structure and color. The latter feature, in particular, would not be appreciable from the physical model alone without the texture (fig. 8).
In fact, user involvement requires the integration of effective tools of cultural fruition, thought, in the specific case, in the integration of new modes of information fruition [Empler 2018, p. 13.10] and in the iteration of the real and the virtual model, through the realization of a digital vitrine where to display the surveyed object, connected in an augmented reality experience, also usable in a traditional way on a transparent screen [Bimber, Encarnação, Schmalstieg 2003, pp. 87-95]. Specifically, for the creation of the display case, the components of an Acer LCD monitor were reassembled into the digital showcase, structured to fit the material prototype into a 'new space' between the different layers of the LCD and the backlight (fig. 8). The showcase was sized and designed to be equipped with a new backlighting system, by means of 5 LEDs of 40W and 3600 LM, to achieve uniform brightness and perfect visibility of the digital content on the screen, which acts as a front glass protecting the exhibited object (fig. 9). The screen was then connected to an external computer for sharing content, and AR app tracking systems was adapted for the display case and the printed object. This resulted in a prototype that, in the integration of the digital reconstruction and integration phases between real and virtual [D'Acunto 2012, pp. 273-278], is placed in the museum environment with reference to natural lighting conditions so that they do not interfere with the proper digital enjoyment of the content (fig. 10).

Conclusions and future developments

The goal, to digitize and model the holdings of the scientific collections –in agreement with MUSA for the new museum display of the entomological and zoological sector– has been achieved by highlighting the support of new technologies that, if critically integrated, can expand the knowledge of artifacts in the interconnection between real and virtual, responding positively to the content-container question on which the museum idea is based. It should be emphasized that the work done so far is intended to be a highly experimental process; in consideration especially for future developments that are moving toward the integration of showcase touch [Yang, Wang 2009, p. 75132U], it is not a point of arrival but a starting point for further experimentation that can delve into certain issues such as the lack of authenticity of the asset that differs from the original in materials, colors, textures and the most minute details. Hence, this contribution represents a first step for the recovery of the material model in the medium of rapid prototyping and integration with augmented fruition, addressed to a popular and research use guaranteeing the protection of delicate, fragile and of great scientific value collections that need, therefore, to be safeguarded thanks to the application of new information and communication technologies.

Credits

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Reference List

Allam, Z., Sharifi, A., Bibri, S.E., Jones, D.S., Krogstie, J. (2022). The Metaverse as a Virtual Form of Smart Cities: Opportunities and Challenges for Environmental, Economic, and Social Sustainability in Urban Futures. In *Smart Cities*, Vol. 5, No 3, pp. 771-801.

Ballarin, M., Balletti, C. Vernier, P. (2018). Replicas in cultural heritage: 3D printing and the museum experience. In *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Vol. XLII-2, pp. 55-62.

Bertacchini, E.,Morando, F. (2013). The Future of Museums in the Digital Age: New Models of Access and Use of Digital Collections. In *International Journal of Arts Management,* Vol. 15, No 2, pp. 60-88.

Bimber, O., Encarnação, L. M., Schmalstieg, D. (2003). The virtual showcase as a new platform for augmented reality digital storytelling. In *Proceedings of the Workshop on Virtual Environments* 2003, pp. 87-95. ACM.

Bolognesi, C., Aiello, D. (2020). LEARNING through SERIOUS GAMES: A DIGITAL DESIGN MUSEUM for EDUCATION. In *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, Vol. XLIII-B5, pp. 83-90.

Cameron, F. (2010). Museum Collections, Documentation, and Shifting Knowledge Paradigms. In P. Ross (Ed). *Museums in a Digital Age*, pp. 80-95. London: Routledge.

Cicerchia, A., Solima, L. (2020). *E ora...? Primi risultati dell'indagine condotta sui pubblici dei musei italiani durante il lockdown*. Rapporto di ricerca, Mibact - Dg Musei, Typescript, pp. 1-27.

D'Acunto, G. (2012). Augmented Reality and Museum Exhibition. The Reconstruction of the Statues of The Tribuna of Palazzo Grimani in Venice. In A. Giordano, M. Russo, R. Spallone (Ed.). *Representation Challenges. Augmented Reality and Artificial Intelligence in Cultural Heritage and Innovative Design Domain*, pp. 273-278. Milano: FrancoAngeli.

D'Agostino, P., Antuono, G. Elefante, E. (2022). Management and Dissemination for Dismissed Religious Architecture. An Approach Fusing HBIM and Gamification. In *EGA 2022: Architectural Graphics*, Vol. 2, Graphics for Knowledge and Production, pp. 399-407. Berlin: Springer.

Empler, T. (2018). Traditional Museums, virtual Museums. Dissemination role of ICTs. In *DISEGNARECON,* Vol. 11, No 21, pp. 13.1-13.19.

Hooper-Greenhill, E. (2003). Nuovi valori, nuove voci, nuove narrative: l'evoluzione dei modelli comunicativi nei musei d'arte. In S. Bodo (a cura di). *Il museo relazionale. Riflessioni ed esperienze europee,* pp. 1-40. Torino: Fondazione Giovanni Agnelli.

Huggett, J. (2020). Virtually real or really virtual: towards a heritage metaverse. In *Studies in Digital Heritage*, Vol. 4, No 1, pp. 1-15.

Huhtamo, E. (2010). On the Origins of the Virtual Museum. In R. Parry (Ed.). *Museums in a Digital Age,* pp. 121–135. London: Routledge.

Ippoliti, E., Albisinni, P. (2016). Musei Virtuali. Comunicare e/è rappresentare. In *DISEGNARECON,* Vol. 9, No 17 pp. E1-E15.

Kang, Y., Yang, K. C. C. (2020). Employing Digital Reality Technologies in Art Exhibitions and Museums: A Global Survey of Best Practices and Implications. In G. Guazzaroni, A. S. Pillai (Ed.). Virtual and Augmented Reality in Education, Art, and Museums, pp. 139-161. Hershey, Pennsylvania: IGI Global.

Khunti, R. (2018). The Problem with Printing Palmyra: Exploring the Ethics of Using 3D Printing Technology to Reconstruct Heritage. In *Studies in Digital Heritage,* Vol. 2, No 1, pp. 1-12.

Liva, G. (2021). Digital identities. Technologies for the Conservation, Reconstruction and Fruition of the Sculptural Heritage. *DISEGNARECON,* Vol. 14, No 27, pp. 12.1-12.20.

Neumüller, M., Reichinger, A., Rist, F., Kern, C. (2014). 3D Printing for Cultural Heritage: Preservation, Accessibility, Research and Education. In M. Ioannides, E. Quak (Ed.). *3D Research Challenges in Cultural Heritage,* pp. 119-134. Berlin: Springer.

Oppitz, M., Tomsu, P. (2018). Building the Internet. In M. Oppitz, P. Tomsu (Ed.). *Inventing the Cloud Century. How Cloudiness Keeps Changing Our Life, Economy and Technology,* pp. 201-227. Berlin: Springer.

Papa, L. M., Antuono, G., Cerbone, A. (2020). Re-construction and virtual fruition of a fourteenth-century religious architecture. In C. Gambardella, C. Cennamo, M. L. Germanà, M. F. F. Shahidan, H. Bougdah (Ed.). *Advances in Utopian Studies and Sacred Architecture*, pp. 41-50, IEREK Interdisciplinary Series for Sustainable Development. Springer-ASTI Book Series.

Parry, R. (2010). The practice of Digital Heritage and the Heritage of Digital Practice. In R. Parry (a cura di). *Museums in a Digital Age,* pp. 1-8. London: Routledge.

Sdegno, A (2018). Rappresentare l'opera d'arte con le tecnologie digitali: dalla realtà aumentata alle esperienze tattili. In A. Luigini, C. Panciroli (a cura di). *Ambienti digitali per l'educazione all'arte e al patrimonio*, pp. 256-271. Milano: FrancoAngeli.

Sherman, W. R., Craig, A. B. (2018). *Understanding virtual reality: interface, application, and design,* Second Edition. Elsevier Morgan Kaufmann.

UNESCO (2015). *Recommendation concerning the Protection and Promotion of Museums and Collections, their Diversity and their Role in Society*. Ultimo accesso, 25 Giugno 2022, vedi http://unesdoc.unesco.org/ images/0024/002463/246331m.

Yang, T., Lu, Y., Wang, Y. (2009). Novel interactive virtual showcase based on 3d multitouch technology. In *2009 International Conference on Optical Instruments and Technology: Optoelectronic Imaging and Process Technology,* Vol. 7513, p. 75132U. International Society for Optics and Photonics.

Wilson, P. F., Stott, J., Warnett, J. M., Attridge, A. Smith, M. P., Williams, M. A. (2018). Evaluation of Touchable 3D-Printed Replicas in Museums. In *The Museum Journal,* Vol. 60, No 4, Wiley, pp. 445-465.