Virtual Reality in Future Museums

Maria Grazia Cianci
Daniele Calisi
Stefano Botta
Sara Colaceci
Matteo Molinari

Abstract

The current global situation underlined the necessity of new accessibility standards in the field of cultural dissemination. Due to the limitations defined to contain the pandemic, the process of digitalization of art and knowledge increased its speed, exploiting practices and technologies which once were commonly used in specific sectors. In this climate of fervent developments, the use of Virtual Reality is growing as a medium to convey information, working on themes like immersivity, interactivity and simulation, and considering the previous experimentations in cinematography and videogames, to define experiences which connect sensory perception, engagement and learning. The faithful reconstruction of the Pavilion 2B of the ex Mattatoio di Testaccio in Rome aims to create a virtual environment to be used for digital exhibitions by students and visitors, working on innovative tools to convey art and culture.

Keywords
digital, museum, communication, VR, heritage.

doi.org/10.3280/oa-845-c220

Latest Developments in the Digitalization of Cultural Heritage

During the last decades, a fast and articulate process of digitalization has been carried out in the fields of art and knowledge, aiming at finding new ways to preserve, analyze and communicate culture and places of interest. Many museums, archives and institutions, along with artists and companies specialized in visual and interaction design, digitalize their own collections to make them available online, creating vast catalogs and even virtual tours to provide an immersive and stimulating experience [Antinucci 2007, pp. 94-121]. The Louvre Museum and the Gallerie degli Uffizi both developed partial digital exhibitions, using respectively 360° panoramic pictures and laser scanning to create models where the visitor can dive in and navigate through hotspots, admiring works and the architecture around, and reading information using interactive elements (Fig. 1). The digital transformation is also one of the main pillars of the program *Horizon Europe 2021-2027*, strictly related to the *Athene Charter* and *London Charte*r in configuring the main aspects behind for the proper ways to digitally represent of architecture and archeology.
Due to the safety restrictions made to stem and control the current pandemic situation, which has changed dramatically people's experience of interaction and movement inside and outside their own countries, this process of digitalization is facing a strong evolutionary impulse, increasingly bringing alternative techniques and modalities of dissemination and use of cultural heritage [Toffoletti 2021, pp. 15-45]. The ultimate purpose is possibly the research for a wider and more articulate accessibility, capable of allowing everyone to engage with culture and knowledge, everywhere and anytime, incentivizing inclusivity and overcoming the crisis caused by the pandemic to the ordinary communicative paradigms.
In a fervent climate of investigation, the choice of developing Virtual Reality as a medium for the dissemination of art and knowledge could address these necessities with innovative ways yet to be explored, providing a different model for transmitting information and unveiling new meanings in the relationship between people and cultural heritage.

Virtual Reality in Architectural Communication

The use of Extended Reality (XR), in its multiple forms, is expanding as a new and alternative tool to understand and interface with the historical and artistic heritage, both material and immaterial, allowing deep and diachronic investigations. In this evolution, cinematographic and videogame industries hold a substantial role, being among the first fields to invest on digital innovation and having worked for decades on themes like immersivity, simulation and the direction of human perception. Interdisciplinarity and contamination among fields are vital to build a concrete and valuable research project, working on the boundaries among disciplines.

Fig. 1. Screens taken from the virtual tours created by Louvre (left) and the Uffizi (right).

Among the many variations took by XR, Virtual Reality (VR) consist in creating a completely artificial environment using sensory stimuli generated by devices, where Augmented Reality (AR) can be seen as a real-time overlay of information and actions over physical world images captured by a device. Being profoundly related to the tridimensional representation of a space, VR has a solid connection to architecture, landscape and environment, making this medium suitable to investigate and communicate these themes [Greenard 2019, pp. 37-53]. Exploiting advanced technologies and VR, it is possible to create reconstructions of real places, with different levels of accuracy and resemblance to the original, which can be used to set up alternative experiences of exhibitions and visits, working on immersivity and interaction with the virtual environment as key-points to capture users' attention, blending information with entertainment, in order to convey a message through engagement. VR guarantees the opportunity to create and experience spaces free from the limitations imposed by physical reality, especially when it comes to cultural heritage and its conservation. It allows the users to explore distant places, sites inaccessible due to their conditions, faithful reconstruction of destroyed buildings, or even parallel realities in which unbuilt architectures can find their own location and show a different look of a landscape "that could have been" [Cianci 2019, pp. 1357-1366].
The representation of architecture and spaces has developed to become closer to reality, trying to simulate all its qualities. Starting from perspectives, continuing with digital renders, the perception of the reproduction has become even more faithful and detailed, but the architectural imagery remains detached from the observer, who usually doesn't have an active role and undergoes the bidimensional image. The main turning point produced by Virtual Reality is the break with the limited frame given by the physical medium: through devices like Head-mounted displays (HMD), it is possible to explore the scene all around with a wider degree of freedom, opening at new ways to understand, design and communicate architecture from the inside, experimenting spaces directly in first person.
This powerful achievement, which unfolds an unlimited range of possibilities of interaction, also causes an interesting issue when it comes to narrate a place: traditional methods for directing and manipulating the users' attention cannot contain their autonomy in choosing how to experience the virtual environment, as far as many compositive rules lose their strength and need to be revised. In a virtual environment, the dynamic, articulated and multidirectional space creates a challenge for storytelling, as it is difficult to transmit information neatly and coherently without a "backstage" to hide ploys and special effects [Butcher 2017, pp. 80-126]. Therefore, the narration of a digital space must be designed through the entire navigable area, as the audience is part of the stage, working on users' perception and behavior to channel or divert their interest, using alternative elements like spatialized sounds, optical alterations, lights and movements, or even trying to trigger sensory stimuli by using synesthetic stratagems. Furthermore, by introducing new devices and techniques to simulate senses, other than VR displays, it is even possible to reach a deeper connection with digital replicas, reproducing a richer quantity of data which can help communicating the subject in a more complete and unique way [Riccò 2008, pp. 28-32].

Related Case Studies

Among the many experimentations of virtual museums developed during the last decades, an original case study was carried out in Buenos Aires by the *Centro de Investigaciones Ópticas* and the *Falcultad de Ingeniería de la Universidad Nacional de La Plata* [Loaiza Carvajal 2020, pp. 234-239]. Not only the project works on creating a virtual museum for cultural heritage dissemination, combining Captured Reality and 3D manual modelling, it also aims to produce a synergy among different curatorial teams to convey two unique and rich virtual tours.
In *Virtual Collections* exhibition, Structure from Motion technique was used to capture detailed reconstructions of heritage manufacts (Fig. 2a), using drones for bigger objects; then, they were simplified to be usable in a fluid real-time application. The architectural space, the signage and the supporting furniture were designed and modeled by the team to emphasize

the objects, paying attention to users' eye fatigue in reading digital descriptions through an HMD. The exhibition didn't have a specific orientation, so the circular path can be followed freely by the visitor, starting from any point.
Krause. Vestigios disponibles exhibition primarily contains drawings, paintings, models and a collage of photographs, so Captured Reality was used for fewer manufacts, choosing to digitize the rest and use it as textures to apply on simple surfaces; this process lightened the model, made it easier to be used for the virtual tour. In this case, the museum was mostly reproduced with manual modelling to communicate the collection with lights and furniture close to the original.
Both the applications were developed in Unity game engine and thought to be used first on computer screens, and then implemented for HMDs. Users can navigate pointing at the place to reach and pressing a button, guaranteeing a free exploration of the museums (even if not continuous and fluid). Manufacts can be look closely but manipulations are not allowed, as it happens in almost every museum.
A particular case study is the virtual museum of Regolini-Galassi Tomb in Cerveteri, a research born within the European project *Etruscanning* [Pietroni 2014, pp. 1-29]. The team focused on the recreation of a deep and detailed simulation of the scene, capturing users' attention through their senses to convey themes ranging from landscape to archeology and ethno-anthropology. The site is one of the richest and most famous tombs of the Orientalizing period, dated 675-650 a.C. and discovered in 1836. It's inaccessible and almost empty nowadays.
The main point of the project was to investigate new ways of experiencing cultural and landscape heritage by introducing a fictional storytelling to evocate an imagery and narrate funeral rites in a suggestive journey. By mixing VR systems and Captured Reality, the team articulated a complex scenario using Unity game engine, generating a digital environment, true to the original site, and using it as the ideal stage to exhibit photo-modeled artifacts (Fig. 2b), hypnotizing their exact location in the tomb and giving them an interactive role.
Two voices, representing the people buried in the tomb, accompany visitors, narrating their own stories through relics and ordinary tools, which can be selected and analyzed to get descriptions. It's an escamotage to captivate users and obtain an improved willingness to learn. Similarly, sensory stimuli were used to direct users through their experience, while preserving their freedom: spatialized sounds from the forest outside the tomb-museum; dynamics lights from torches to progressively unveil the environment, hidden in the darkness of the night. The project also implemented a wider range of senses to the virtual experience, introducing the kinetic element as an immersive form of connection between users and virtual exploration, increasing the embodiment, the feeling of "being really there", to better and actively channel information through engagement. In a dark room, visitors take place in front of a screen and a sensor captures the gestures of their arms, moving the camera accordingly, so the body participate actively in navigating the museum.

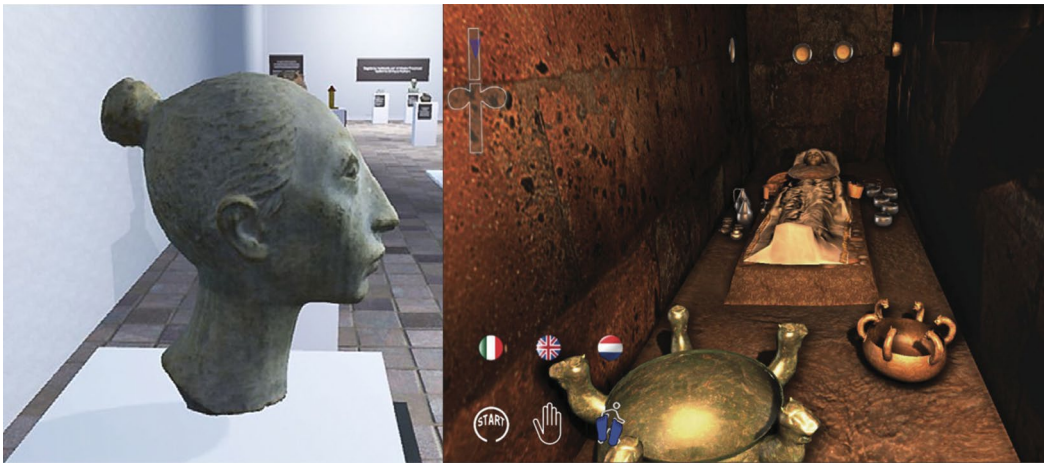

Fig. 2. Screens from two case studies analyzed: (a) a photogrammetric model of a cement head sculpture; (b) relics inside the Tomb Regolini-Galassi.

Creating the Pavilion 2B Exhibition

The project aimed to recreate a faithful reconstruction of one of the pavilions of the *ex Mattatoio di Testaccio* in Rome and use it as a virtual museum to host temporary exhibitions for students and visitors. Exploiting the infinite possibilities of a digital environments, capable of things not allowed in the physical world, the research focused on creating a support scenario for multiple experiencing, combining VR features, sensory suggestions and entertainment elements to communicate art and culture in multiple forms.
Built between 1888 and 1891, the new slaughterhouse was design by Gioacchino Ersoch in the Testaccio neighborhood to replace the previous one realized in Piazza del Popolo. Characterized by a rational distribution of functions to guarantee a better hygiene and surveillance, the area was divided in pavilions, which were built using masonry walls, marble, iron structures and wooden roofs. The pavilion 2B, the one chosen for the study, contained stables for tamed cattle, right next to the main entrance of the complex. The slaughterhouse was dismissed in 1975, assuming various functions through time, and becoming part of the *Città delle Arti* restoration project, housing the Architecture Department of Roma Tre University since 2000. The Pavilion 2B was completely restored in 2013 and intended for classrooms and laboratories, exploiting its structural subdivisions to implement movable walls, creating an open and flexible space for multiple uses.
During the first stage, a replica of the pavilion was developed as a direct tridimensional reference to help designing the museum later, optimizing the control over the process. To do so, a photogrammetric survey was planned inside and outside the building, paying attention to the link between the parts. Using a reflex camera and working on cylindrical panoramic shooting through selected points on the axis, the interiors were captured, leaving some blind spots due to the articulation of the upper part of the building, especially because of the iron rails and the skylight. The two external facades were easily captured using parallel axis shooting, while it was not possible to obtain a complete survey of the roof, which should have been made using a drone. This step was avoided for time and authorizations issues, giving more attention to the inside of the pavilion. Furthermore, the role of the photogrammetric reconstruction was primarily to have a faithful reference for the actual model, which was later build manually starting from original drawings and implemented with current element. This choice was made to better manage its heaviness and complexity, two essential parameters for a fluid and practical real-time experience. Choosing a Captured Reality version of the pavilion to design the museum would have required much higher technological resources, made it less usable for ordinary devices [Basso 2019, pp. 2414-2425]. Photos were then selected, edited and imported in Photoscan to create a point cloud of the pavilion (Fig. 3a), which was cleaned, meshed and textured, before being exported. The pavilion 2B was then manually modeled in Rhinoceros, using digital drawings obtained by scans of the original project and other resources provided by AUT catalogue [1] (Fig. 3b). It focused on giving a detailed representation of the interiors, paying attention to materials and the relationship between original and added components; outside, the environment was simplified to just guarantee an immersive but light context to the scene.

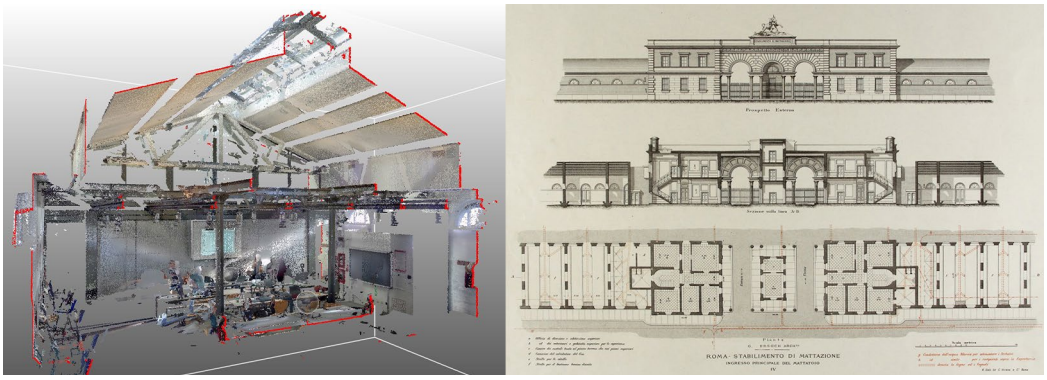

Fig. 3. References for the digital reconstruction of the pavilion: (a) sectioned photogrammetric model of the current state of the Pavilion 2B; (b) one of the original drawings for the Mattatoio's project.

To design a virtual museum for the first exhibition, a masterplan was developed, considering principally three themes: the collections involved, the relationship with the appearance of ex-industrial pavilion and the tight subdivision its interiors. The catalogues chosen for the first experimentation contained drawings and models elaborated by students, divided in various themes, going from the study of spatial complexity and Purini's works, to Manifestos, Terragni's unbuilt projects and Italo Calvino's *Città Invisibili*. Three groups elaborated ideas, which were later merged into a single cohesive plan (Fig. 4). It was decided to give each of the seven areas a subject, generating a double path from the entrance, following two narrative strands to be visited in a free but consequential way. The masterplan almost totally hid the pavilion from the visual plane of the users, made it visible just by the ceiling. A continuous red ribbon runs through the museum, changing its form and function according to the exhibition, while other surfaces were kept black or white. Small groups focused on designing each of the themed area, balancing the integrity of the masterplan concept with the narrative and the peculiarities of every collection. Ideas mostly used were pedestals, opaque and transparent stands, holographic elements, niches and audiovisual chambers (Fig. 5). Many of the objects were modeled as predispositions to be completed during the latest stage, as it was for lights and manufacts to be animated.

The virtual museum experience was developed in Unreal Engine 4.27, starting from a first-person template to optimize time and coding, as this one already had some preset features, like camera movements, reducing and simplifying programming even for non-experts. This choice was principally made to give the visitor an immersive experience of the museum, working on the sense of embodiment and deep engagement; a first-person point of view would have also allowed a further implementation of stereometric vision and HMD systems. A base model of the pavilion was imported in the project, choosing a specified origin, to create a template for every group. Materials were created to be as close as possible to the originals, using cast iron, plaster, clear glass and concrete for the interiors, marble and bricks for the facades of the Pavilion 2B; the rest of the context was left white, to focus the attention on the main subject. A system of complex collisions was then generated, starting from

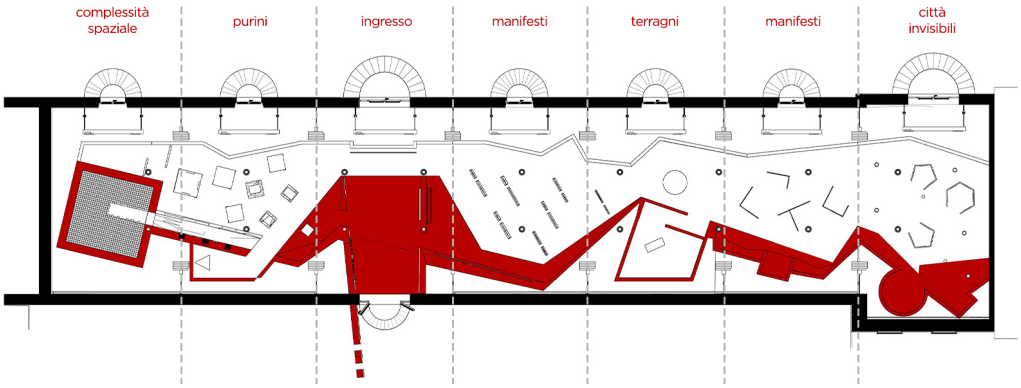

Fig. 4. Masterplan of the virtual museum, created by selecting and merging ideas from three different concepts.

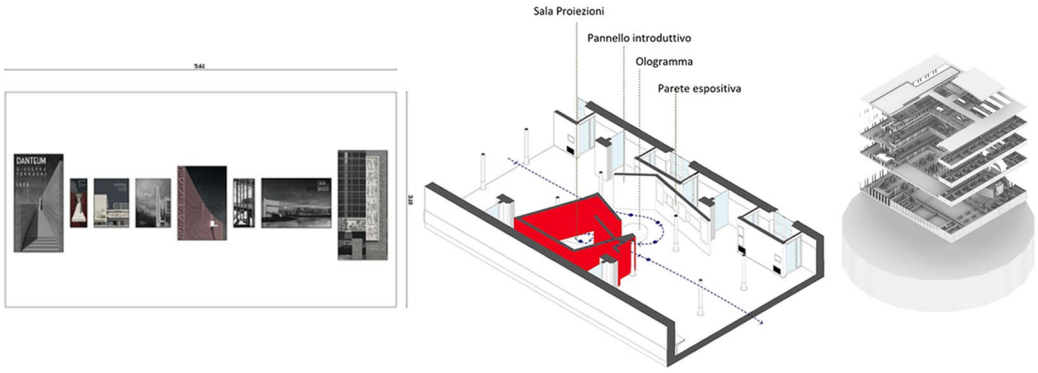

Fig. 5. Project concepts showing the process of designing the exhibition, from selecting and organizing works (left), to defining paths and functional areas (center), to creating models for animations (right).

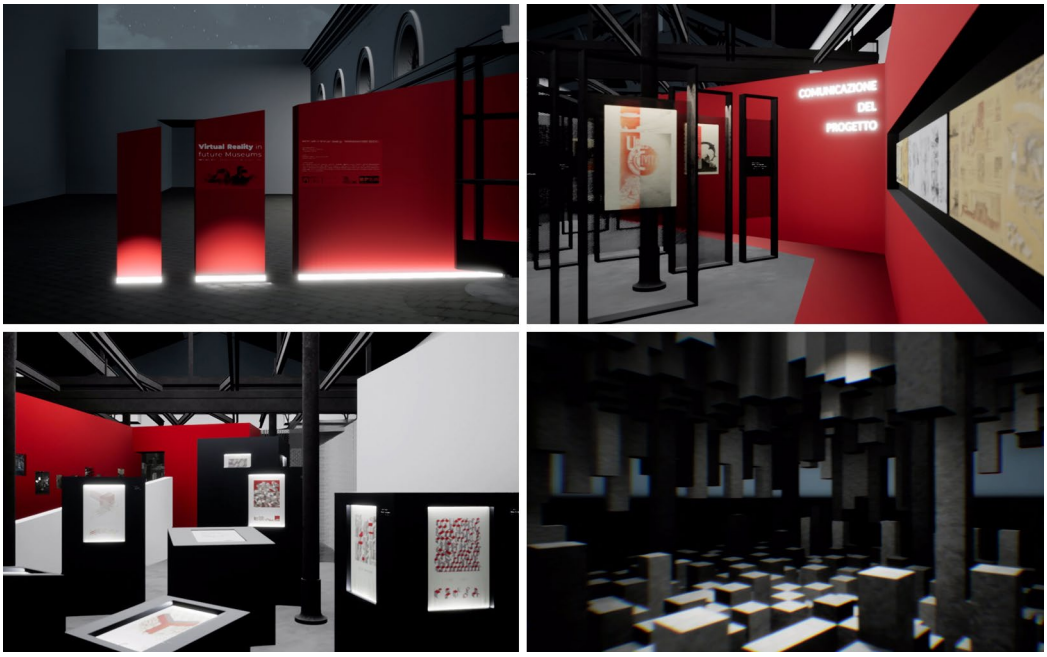

Fig. 6. Screens taken inside the virtual simulation. From top left: the totem at the entrance; Manifestos; Purini's works; inside the Cube Chamber (Spatial Complexity).

the model's meshes, to simulate the physical constrains in the virtual experience. Each group imported its own part of the museum on a copy of the base project, using the same origin, to keep the possibility of working separately and then merging all the results together. This optimized the development of the seven parts of exhibition but gave some issues later, in importing and reorganizing the scenes, as some minor unintentional changes created differences with the original model, which were easily fixable but delayed the process.
For each area, groups imagined interactive elements to engage the users and better convey information. Drawings were used as materials and applied to surfaces with the same proportions to simulate actual artboards. Objects were programmed using *Trigger Volumes* to activate animations or special effects when the visitor entered their area. Some videos, like an interview to Purini and some Terragni's works, were used to create cinematic rooms.
The experience was imagined to be an evening exhibition to enhance its lighting design, which was thought both to direct users' attention on artworks and narrating them through a fluid sequence of dark and bright areas, introverted chambers and surreal spaces.
Spatialized sounds and visual effects were also used as key elements for creating a multisensory exploration, not only to articulate different areas with a dedicated atmosphere, but also to create suggestive imageries, as it was for the cavern echoes and altered colors in the *Cube Chamber*, or telling stories, as for the lens flare effects and narrating voices in representing Calvino's *Città Invisibili*.

Conclusions and Further Applications

Starting the simulation outside the Pavilion 2B, visitors are invited in by the red stripe, which becomes a totem to describe the evening exhibition. Going inside, music and holographic descriptions of the building welcomes them, giving some direction to users and letting them choose how to explore the museum in total freedom, generating an immersive and interactive experience which brings them to get in touch with multiple themes thanks to an alternative reality made it possible by the virtual environment (Fig. 6).
Though there were some issues during the process, mainly deriving from time and technological resources, the project developed allowed to experience new tools and methods for communicating arts, exploiting techniques which could lead to innovative paradigms for the dissemination of culture, and giving a virtual stage ready for future exhibitions. Further appli-

cations considered are the extension of the exhibition to the external areas of the *Mattatoio*, adding new parts to the Pavilion 2B, and the investigation of new interactive features to help the engagement and the transmission of information, like commands and other complex animations. The implementation of HMD and binocular vision to deepen the experience is also one of the main themes to be pursued in a future development.

Notes

[1] AUT – Archivio Urbano Testaccio is a documentation center, born as part of research fields of the Department of Architecture of Roma Tre University, which focuses on the study of Testaccio neighborhood and the ex Mattatoio.

References

Antinucci Francesco (2007). *Musei Virtuali. Come non fare innovazione tecnologica*. Roma-Bari: Laterza.

AUT - Archivio Urbano Testaccio.
http://aut.uniroma3.it/?page_id=183 (13 February 2022).

Basso Alessandro, Calisi Daniele (2019). Acquisition and interactivity of 3d representation connected with the virtual heritage. In Conte Antonio, Guida Antonella (eds.). *ReUso L'intreccio dei saperi per rispettare il passato interpretare il presente salvaguardare il futuro*. Roma: Gangemi, pp. 2414-2425.

Butcher John (2017). *Storytelling for Virtual Reality: Methods and Principles for Crafting Immersive Narratives*. London: Routledge.

Cianci Maria Grazia, Calisi Daniele, de Lorenzo Antonio (2019). La realtà virtuale immersiva per la conoscenza del patrimonio culturale: il quartiere Alessandrino a Roma. In Conte Antonio, Guida Antonella (eds.). *Patrimoni in divenire. Conoscere, valorizzare, abitare. Atti del VII Convegno Internazionale sulla documentazione, conservazione e recupero del patrimonio architettonico e della tutela paesaggistica ReUSO 2019*. Roma: Gangemi, pp. 1357-1366.

Greengard Samuel (2019). *Virtual Reality*. Cambridge: MIT Press Edition.

Toffoletti Isabella (2019). *Chiusi per Covid. Aperti per cultura. Musei e Comunicazione digitale. Bilancio e Prospettive*. Roma: Gangemi.

Le Gallerie degli Uffizi (2019). La Sala delle Dinastie e le Sale del Cinquecento veneziano.
https://www.uffizi.it/mostre-virtuali/uffizi-virtual-tour (13 February 2022).

Loaiza Carvajal Daniel Alejandro, Morita María Mercedes, Bilmes Gabriel Mario (2020). Virtual museums. Captured reality and 3D modeling. In *Journal of Cultural Heritage*, 45, 2020, pp. 234-239.

Petite Galerie Louvre.
https://petitegalerie.louvre.fr/visite-virtuelle/saison6/ (13 February 2022).

Pietroni Eva, Adami Andrea (2014). Interacting with Virtual Reconstructions in Museums: The Estruscanning Project. In *ACM Journal on Computing and Cultural Heritage*, 7 (2), 2014, pp. 1-29.

Riccò Dina (2008). *Sentire il design. Sinestesie del progetto di comunicazione*. Roma: Carocci.

Authors
Maria Grazia Cianci, Dept. of Architecture, University of Roma Tre, mariagrazia.cianci@uniroma3.it
Daniele Calisi, Dept. of Architecture, University of Roma Tre, daniele.calisi@uniroma3.it
Stefano Botta, Dept. of Architecture, University of Roma Tre, ste.botta@stud.uniroma3.it
Sara Colaceci, Dept. of History, Representation and Restoration of Architecture, Sapienza University of Rome, sara.colaceci@uniroma1.it
Matteo Molinari, Dept. of Architecture, University of Roma Tre, matteo.molinari@uniroma3.it

Isbn 9788835141945