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RETHINKING LIGHTING AND COMMUNICATION FOR A CULTURAL ASSET, A CASE STUDY: THE ROMAN VILLA LA CONSOLATA

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Abstract

The Covid-19 pandemic has caused service disruptions in numerous sectors of human activity. Museums and cultural institutions have unfortunately been among them. However, the emergency has put insiders in a position to find solutions to make the works usable in digital mode, applying research and technologies that have been the subject of research over the last twenty years. In this contribution, a case study will be considered related to an archaeological site museum of a Roman villa, which suffered from usability problems long before the pandemic. Some possible interventions will be listed to improve readability and communication with potential visitors.

Keywords

Cultural Heritage, Digitalisation, Lighting, Video projections, Virtual museum

1. *Introduction*

In the context of cultural heritage, the enhancement of assets is a fundamental element. Unfortunately, due to geographical location, significant restorations, or interventions aimed at preserving the asset, some sites lose visibility and are deserted by the public to the point that it is disadvantageous to preside and maintain the asset. Fortunately, it is sometimes possible to intervene using techniques that provide for enhancing the site through an approach of digitisation and virtual representation of the place.

This kind of approach is consolidated by over twenty years of research and technological improvements. The purpose of the digitalisation can be the enhancement of the asset (Valzano, Negro, & Lucarella, 2019), the research and focus of ideas deriving from the available material (Frommel, Apollonio, Gaiani, & Bertacchi, 2020), up to its classification in digital collaborative contexts, to allow cross-platform analysis (Apollonio, Gaiani, & Sun, 2012).

The use of digital display technologies, both on acquired and then digitised assets, and on native digital material is varied. Numerous digital application types or presentations can be tracked, including 2D, 3D, panoramic 360° visualisation, photogrammetry, 3D reconstruction, 3D model or laser scan, BIM/VRE technology, and AR/VR applications (Pfarr-Harfst, 2020).

Such a wide variety of options has allowed incredible possibilities of communication to a point where the real challenge, rather than improving the technologies, is the choice of the narrative paradigm, which, making use of the digital potential, is intended to be presented to visitors (Valzano & Mannino, 2020).

However, the decision to implement these technologies has always been linked to research or to the desire to promote a specific cultural asset or to expand its usability outside the geographical context in which it is located.

2. *Cultural heritage and lockdown*

On March 11 2020, the *World Health Organization* declared the COVID-19 pandemic (WHO, 2020). All over the world, with different timings and methods, the need to contain the spread of the virus leads to the closure of unnecessary services and, unfortunately, museums and centres of cultural activity. The desire to take action in this dramatic situation was immediately evident. Thanks to initiatives such as that of the *European Heritage Alliance*, which on May 9 2020, publishes the manifesto *"Cultural Heritage: a powerful catalyst for the future of*

Europe", which includes issues on raising awareness of the pandemic emergency and the importance of digitisation of cultural heritage (European Heritage Alliance, 2020).

After an initial period of adjustment, the museum structures begin to reorganise themselves to make their heritage available in digital form. The solutions undertaken are very heterogeneous and try to make the most of the types of representation described above. Here are some experiments of opening to the public in digital form.

2.1 Solutions for the crisis

In Italy, the *Uffizi in Florence* (Gallerie degli Uffizi, 2021) and the *Vatican Museums* (Musei Vaticani, 2021) have opted for a digital catalogue with high-resolution 2D representations, complete with an ID card for the item in question. The *Egyptian Museum of Turin* (Museo Egizio di Torino, 2021) and the *Gallerie d'Italia of Milan* (Gallerie d'Italia, 2021) have enhanced their websites. They included themed media on the leading social platforms (YouTube, Facebook, Instagram, etc.) and offering the possibility to virtually visit museums or specific exhibitions with 360° panoramic views integrated with textual and video descriptions. In Venice, on the island of San Giorgio Maggiore, two foundations' joint commitment (Pentagram Stiftung Foundation & Fondazione Giorgio Cini, 2021) has reconstructed a digital version of the exhibition *"Venice and American Studio Glass"*. Here, the 360° panoramic views are enriched with audio descriptions and 3D models that can be used directly in the internet browser and VR mode using Oculus technology (Facebook Oculus, 2021).

In addition to the types as mentioned above of digital application and presentation, different promotion approaches have also been introduced; like in the case of the *Arnaldo Pomodoro Foundation* (Fondazione Arnaldo Pomodoro, 2021), which programs online events in real-time, such as the *"Scritture del Labirinto"*, or the *MACRO* (Museo di Arte Contemporanea di Roma) which, in addition to numerous multimedia elements, publishes *Dispatch*, a podcast dedicated to cultural activities (MACRO Museum, 2021).

In the Italian context, another interesting initiative is that of the *3D Virtual Museum* container site (Bigliardi, 2020), which offers an open collection of works acquired through different techniques and made available through internet browser complete with descriptions by those who upload the asset.

Another example of 3D reconstruction is the *Louvre's* initiative in Paris, which, aside from the museum's virtual tour, created an interactive attraction centred on Leonardo da Vinci's Mona Lisa, using HTC's Viveport platform. The project is called *"Mona Lisa: Beyond the Glass"* and allows the visitor to interact with the painting as if it were a door to the "painting's world" (Louvre, 2019).

However, the most common approach for museums' virtual visit remains the presentation through 360° panoramic environments, integrated with written descriptions, audio, video, and sometimes 3D models. Some well-known examples in the world are the Smithsonian National Museum of Natural History in Washington (Smithsonian, 2020), the Palace Museum in Bejing (Palace Museum, 2020), Casa Batlló in Barcelona (Casa Batlló, 2018), the Van Gogh Museum in Amsterdam (360 Stories, 2020) and many more.

Like in the listed examples, many solutions with heterogeneous approaches proved highly accurate and effective, but in other cases, the systems implemented were challenging to use and often incomplete.

2.2 Google Arts & Culture

On the world scene, the giants of communication have moved to intervene in this situation, one above all *Google*. The Californian IT house has launched a non-profit initiative (Google, 2021) to make the contents of museums, art galleries and cultural spaces usable through available technological solutions (such as *Street View*). On the platform's website, it is possible to collaborate with Google to integrate one's cultural reality into the system. Google already has a partnership with more than 2000 cultural institutions in more than 80 countries worldwide (Pascoal, Tallone, & Furtado, 2021).

The site also contains digital experiments in the form of games that help even the youngest to get closer to the works. Still, undoubtedly, the most exciting part is the powering and customisation of world museums' websites. The British Museum, for example, presented a site that acts as an actual online application. The name is "The museum of the world" (British Museum, 2021), allowing one to explore high-resolution 2D images of the museum's assets with audio description. The heritage is presented on a hypothetical timeline (with filters based on the geographical location) and the historical connections with the other elements virtually exposed.

Other examples of well-known museums that have benefited from this service are the National Gallery in London (National Gallery & Google, 2021), the Metropolitan Museum of Art (The Metropolitan Museum of Art & Google, 2021) and the Guggenheim in New York (Guggenheim & Google, 2021) and many others.

3. *A case of study: the Consolata Roman Villa museum*

The case of the *Roman Villa of the city of Aosta* has represented for a long time a problem of fruition, to the point that for years the access to the area has been limited and even blocked. The villa represents a particularity for the regional area.

The site is of the republican epoch, antecedent to the Valley's conquest from the Imperial troops of Augusto (25 BC). The Villa sets behind what was probably the ancient lay-out of that that will become for the Romans the Gauls' road, which allowed the passage of the Alps across to the pass of the Grand San Bernard (Mon Jovis).

The site was probably born as an agricultural or commercial installation and show the remains of a series of walls and floors that allow a clear delimitation of the various environments and the separation of the familiar activities from those more economical (stores).

After her lucky discovery, which happened in the '70, the villa suffered a heavy intervention of museumization intended to separate the site from the residential district in which she has come to find. The proximity to the residential context, however, limits the enjoyment of the archaeological site.

The museum's construction over the site happened at the beginning of the '80. The realisation of a structure to answer the district's housing demands ended with excessively invading the archaeological area. The architectural structures of support in reinforced concrete have, for years, made almost impossible the visits since the building plant ended overhanging the trimmed rests of the existing masonries.

Following a project proposal, ever realised for financial motives, in 1999, an intervention camouflaged the site by painting black the interiors of the architectural structures' incumbent surfaces.

Fig. 1: The structure housing the museum separating it from the urban context. The skylights allowed solar illumination; however, maintenance works (due to infiltrations) and the plastic material ageing reduced natural light.

Fig. 2: The remains of the Roman villa were covered to avoid damage during a restoration in 1999. The interiors of the reinforced concrete structure. Immediately after its construction, the ceiling and walls were painted black.

A programmed tour was designed with the idea to illuminate every single room as the visit progressed.

The purpose was to increase the focus of the attention towards the site, dematerialising the bulky surrounding structure. Even though it met the design intentions, the realisation found short interest from the sector operators, which saw her too much binding. The obligation to follow a specific sequence of lighting switches was not appreciated by the operators, who soon abandoned it, limiting themselves to turning on all the lights and giving an overall description of the site with the consequent loss of specificity of the visit. The administration's goal has always been to find new ways to recall the visitors and, at the same time, to rethink the structure to give a better interpretation of the site.

The first idea remained to use the light to achieve the desired goal by rethinking the lighting system design to free it from the necessity to be operated by service employees.

The scarce consistency of the vertical surfaces and the little readability of the remaining mosaic floorings defined the necessity to seek the possibility to make the deprived parts more identifiable, like the impluvium, the thermal area and that of the kitchens.

To carry out minimally invasive interventions, limiting the risk of damaging the remains, the idea of designing a "dematerialised" system of video projections came from the descriptive panels already present in the museum. By using the light in the form of a video projection, it would have been possible to superimpose (at specific observation points) the ancient appearance of the villa on the ruins in their full respect and safeguard. The reconstruction of the site in 3D was the starting point for the lighting project.

3.1 3D model and lighting computation of the site

A possible solution for the 3D reconstruction of the site could have been the acquisition by laser scanning, but we wanted to avoid interaction with the ruins as much as possible. Another alternative could be photogrammetry, but in the initial phase, the 3D model we wanted to create had to support the lighting verification. Therefore, to be quickly processed by the simulation software, the geometry needed to be simplified. Therefore, we opted for reconstruction by modelling in 3D software to be physically accurate for the following purpose of lighting design and photometric verification.

For the accuracy of calculating the light and images, we have opted for a non-commercial rendering software of unbiased type (Arvo et al., 2001; Khodulev & Kopylov, 1996). We used actual photometric data for lighting fixture computation in the new standard (ANSI/IES, 2019) available from online catalogues published by manufacturers. While for materials, in unbiased rendering computation, scientific research has already dealt with the problem of material management in the context of radiometry through radiometric bidirectional reflectance distribution function (BRDF) with physically more correct solutions than commercial rendering software. There are online databases of the BRDF of many materials (Dana, van Ginneken, Nayar, & Koenderink, 1999; Filip, Vávra, & Mikeš, 2009) available online, and some of the materials of the case study have been measured in previous researches (Gelli, March, Salonia, & Vitulano, 2003; Rossi, Marini, & Rizzi, 2004).

The reconstruction phase began with an inspection of the site and a photographic survey to recover the textures needed for the model. The lighting conditions were not optimal for collecting the images; therefore a subsequent photo editing was required. The site floor plan and some sections were used to create the 3D model of the villa ruins and the concrete building above the villa. The textured model was then imported into the lighting computation software, where various design hypotheses were verified.

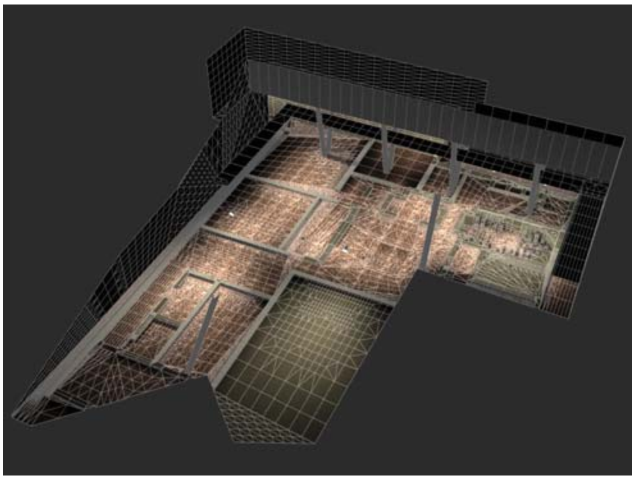

Fig. 3: The polygonal 3D model of the site interiors.

3.2 The lighting project

The lighting of this space immediately proved to be extremely complex; the intervention that involved the darkening of the walls had, as a secondary effect, that of cancelling all the possibilities of relying on indirect light, giving rise to a space that can only be illuminated in a very contrasted and dramatic way.

The upper part of the structure appears lost in an unbridgeable void, while the ruins seem to float in an indefinite and alien space. Repainting the room would have meant making the bulky protective shell reappear, so the lighting project focused only on the lower part of the space.

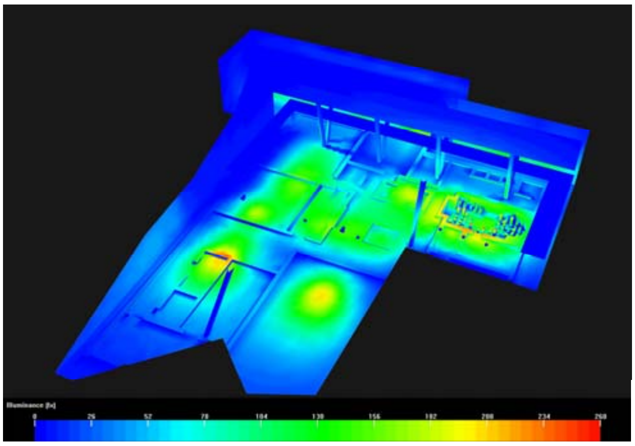

Fig. 4: Non-photorealistic rendering showing the illuminances of the primary illumination of the ruins.

In addition to the mandatory emergency lighting (CEN, 2013), two different lighting scenes were hypothesized in the site's space.

The first was functional to the site's description, illuminating the area entirely or by the individual rooms of the villa. This approach was conceptually not too dissimilar from the idea of 1999, but with the possibility of being carried out without burdening the operators to control it, still, with the option to illuminate the entire surface should the narrative require it. The projectors were not intended to be mounted on the ceiling, as they would have caused excessive glare to visitors. The walkways (and the pillars of the structure) were high enough to install the floodlights to cover the entire surface evenly and profilers to frame the rooms. On the treading areas, on the other hand, LED strips with asymmetrical optics were sufficient to guarantee the lighting levels necessary for a safe passage.

In addition to the functional aspect, the second lighting scenario was enriched by techniques aimed not to illuminate the asset but rather at enhancing the site.

Numerous possibilities would have been feasible (Bimber & Raskar, 2006). Still, in the end, given the size of the site and the need to provide a solution that was also economically sustainable, we opted for the use of video projections. A series of video projectors were installed to project the ancestral aspect of the mosaics on the floors, where they were no longer readable or have been completely lost. The second series of projectors had the purpose of carrying out a front projection on a transparent screen. This technique implies that visitors can observe the site from specific observation points and, on the transparent screens, the superimposed information related to it. The idea would be to project the ancestral aspect of the environment by superimposing it on the ruins. This step requires the reconstruction of the space with a high-resolution three-dimensional model different from the one used for lighting checks. It would also have been possible to think of more complex screens that allowed 360° video projections (Nakamura et al., 2019). Again, intending to contain the budget, we have remained on flat transparent screens.

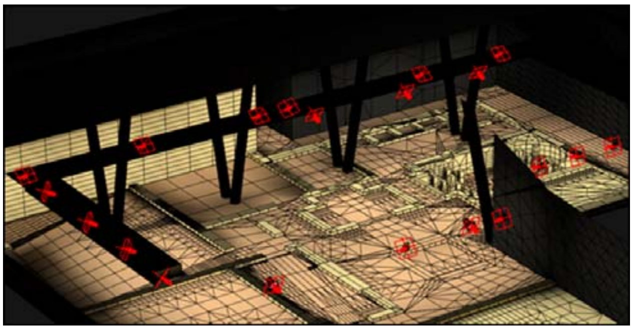

Fig. 5: Position of floodlights and profilers in the area. The installation under the walkways allows the containment of glare towards the visitors.

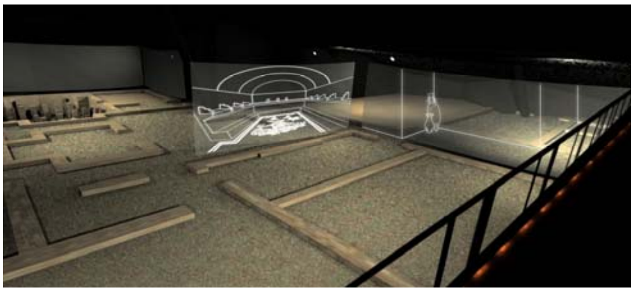

Fig. 6: Projection of the ancestral aspect of the villa on transparent screens.

The images could have been static or animated, depending on the possibility of creating three-dimensional animations and the choice of using a more narrative approach or not.

Given its size, the site could indeed be suitable for reconstructing real-life scenes to make the visit more engaging and focus attention on the site's ambience (Bonn, Joseph-Mathews, Dai, Hayes, & Cave, 2007).

The two main limitations of the projection system were the focal point of the projections and their brightness.

The simplest way to carry out a non-invasive installation of the screens would have been to place them near the walkways on which visitors look at the site; however, this was not possible due to the excessive focal distance between the ruins and the screen. Choosing this solution would have cancelled the effect of overlapping with the remains entirely, and therefore, it was necessary to bring the screens closer to the affected area. This was not optimal as they were visible even when the projections were not turned on. However, because screens were transparent and placed in specific locations, it was possible to circumvent the problem by establishing specific places (not aligned with the screens) where operators could describe the site.

The second limit was given by the brightness of the projection, which was way lower than that of the site's lighting system. This point was particularly crucial as the observation point of the visitors was high above the area, and it was possible to see the illuminated ruins through the screens, which was also necessary to obtain the overlap effect. This problem was solved by sufficiently reducing the brightness of the system when projections were used.

A final possible lighting intervention (although not initially planned) was related to the use of UVGI (Ultraviolet Germicidal Irradiation) lighting equipment (Kowalski, 2009). The museum suffered from water infiltration issues on the perimeter walls, which lead to the proliferation of yeasts. The installation of emission devices in the UVC field, to be used only during closing hours, could have reduced the problem. However, it is difficult to imagine these systems applied to any other place than the perimeter walls because of the risk of damaging the pigments in the remaining mosaics.

3.3 Virtualisation to improve visibility in lockdown

Unfortunately, for various reasons, the project has not yet been implemented on the site. To date, due to the restrictions given by the pandemic, the villa museum is closed to the public. Still, even when it was open to visitors, the numerous closures made it difficult to enjoy this valuable find. The most common review platforms (Google reviews, TripAdvisor, etc.) show a clear interest in the archaeological area. Still, the negative comments are focused on the reduced usability and poor valorisation of the site.

A possible method to advertise the space and communicate it in the best possible way is to create a virtual version of the villa, making it available on the internet. As described above, there are numerous approaches to virtual museums, although the most widespread is still the use of 360° panoramic images integrated with information on the assets. The diffusion of this solution is probably due to the relative simplicity of realization and the lower cost compared to a reasonably accurate result (photographic). 3D reconstructions require the use of specific equipment and skills, and in the case of extensive and material-rich museums, this can be a deterrent. There is much literature on the design and construction of virtual museums (Kersten, Tschirschwitz, & Deggim, 2017; Pedersen, Gale, Mirza-Babaei, & Reid, 2017) and decades of research on possible approaches for the digitization of cultural heritage (Ahmed et al., 2021; Bruno et al., 2010).

In the case of the Villa della Consolata in Aosta museum, however, the size of the site, the lack of verticality and artefacts would make the 3D model created for the study of lighting and communication can be easily transformed into a virtual 3D model that can be visited online. The 3D model created and the calculation system are very well suited to implementation in the X3D format for and Internet virtual access to the museum (Web3D Consortium, 2021). This would allow access to an augmented 3D virtual reality capable of enhancing the villa museum through the lighting design and communication interventions also aimed at improving the actual site.

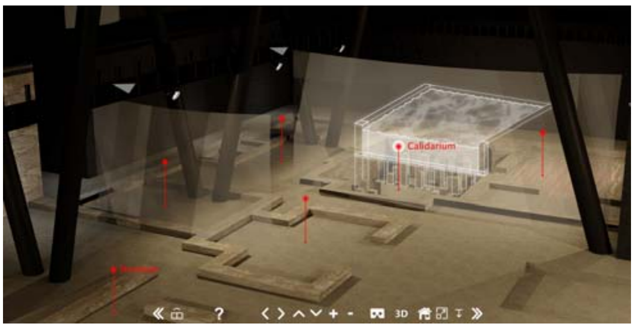

Fig. 7: Implementation of the created 3D model in the X3D format to grant access to navigation and VR features

4. Conclusions and future outlook

This article presented the most common solutions used in museums worldwide during the lockdowns imposed by the Covid-19 pandemic.

The case study of an underused archaeological museum was then presented, for which possible solutions were identified to improve the readability and usability. The redesign of a new lighting system was then described. The new hypothesis could allow the smart control of the lighting fixture, also in relation to the position of visitors in the space.

Numerous interventions at levels of increasing complexity could be adopted to give the site increased visibility and make it accessible to a broader audience. The scalable complexity of the entire installation could depend on the economic investment available to enhance the villa. This also includes the choice of implementing a virtual visit based on X3D technology, via web browser, or through the use of VR equipment, which will be the next step of this research project to allow a comprehensive virtual visit to this museum

REFERENCES

360 Stories. (2020). 360 Stories [Virtual tour service]. Retrieved April 15, 2021, from 360 Stories website: https://360stories.com/amsterdam/point/van-gogh-museum-8

Ahmed, H. O., Belhi, A., Alfaqheri, T., Bouras, A., Sadka, A. H., & Foufou, S. (2021). A Cost-Effective 3D Acquisition and Visualization Framework for Cultural Heritage. In X.-S. Yang, S. Sherratt, N. Dey, & A. Joshi (Eds.), *Proceedings of Fifth International Congress on Information and Communication Technology* (pp. 495–503). Singapore: Springer Singapore. https://doi.org/10.1007/978-981-15-5859-7_49

ANSI/IES. (2019). *LM-63-19—Approved Method: IES Standard File Format for the Electronic Transfer of Photometric Data and Related Information*. IESNA. Retrieved from IESNA website: https://webstore.ansi.org/standards/iesna/ansiieslm6319

Apollonio, F. I., Gaiani, M., & Sun, Z. (2012). BIM-based Modeling and Data Enrichment of Classical Architectural Buildings. *SCIRES-IT, 2*(2). https://doi.org/10.2423/i22394303v2n2p41

Arvo, J., Fajardo, M., Hanrahan, P., Jensen, H., Mitchell, D., Pharr, M., & Shirley, P. (2001). *State of the Art in Monte Carlo Ray Tracing for Realistic Image Synthesis*. 1–192. Los Angeles, CA.

Bigliardi, G. (2020). 3D Virtual Museum [Virtual Museum]. Retrieved February 15, 2021, from 3D Virtual Museum website: http://www.3d-virtualmuseum.it/

Bimber, O., & Raskar, R. (2006). Modern approaches to augmented reality. *ACM SIGGRAPH 2006 Courses on - SIGGRAPH '06*, 1. Boston, Massachusetts: ACM Press. https://doi.org/10.1145/1185657.1185796

Bonn, M. A., Joseph-Mathews, S. M., Dai, M., Hayes, S., & Cave, J. (2007). Heritage/cultural attraction atmospherics: Creating the right environment for the heritage/cultural visitor. *Journal of Travel Research, 45*(3), 345–354. Scopus. https://doi.org/10.1177/0047287506295947

British Museum. (2021). The Museum of the World [Virtual Museum]. Retrieved February 9, 2021, from Museum of the World website: https://britishmuseum.withgoogle.com/

Bruno, F., Bruno, S., De Sensi, G., Luchi, M.-L., Mancuso, S., & Muzzupappa, M. (2010). From 3D reconstruction to virtual reality: A complete methodology for digital archaeological exhibition. *Journal of Cultural Heritage, 11*(1), 42–49. https://doi.org/10.1016/j.culher.2009.02.006

Casa Batlló. (2018). Casa Batlló—Virtual tour. Retrieved February 15, 2021, from Casa Batlló website: https://www.casabatllo.es/en/virtual-tour/

CEN. (2013, September 19). *EN 1838:2013—Lighting applications - Emergency lighting*. Comité européen de normalisation.

Dana, K. J., van Ginneken, B., Nayar, S. K., & Koenderink, J. J. (1999). Reflectance and texture of real-world surfaces. *ACM Transactions on Graphics, 18*(1), 1–34. https://doi.org/10.1145/300776.300778

European Heritage Alliance. (2020, May 9). *Europe Day Manifesto "Cultural Heritage: A powerful catalyst for the future of Europe."* Europa Nostra. Retrieved from https://www.europanostra.org/wp-content/uploads/2020/05/20200509_EUROPE-DAY-MANIFESTO.pdf

Facebook Oculus. (2021). Oculus | VR Headsets and Equipment [Commercial]. Retrieved February 9, 2021, from https://www.oculus.com/?locale=en_GB

Filip, J., Vávra, R., & Mikeš, S. (2009). UTIA BTF Database—Database. Retrieved April 11, 2021, from http://btf.utia.cas.cz/?brdf_dat_dwn

Fondazione Arnaldo Pomodoro. (2021). Le scritture del LabirintoWorkshop online [Cultural foundation]. Retrieved February 9, 2021, from Fondazione Arnaldo Pomodoro website: https://www.fondazionearnaldopomodoro.it/prodotto/le-scritture-del-labirintoworkshop-online/

Frommel, S., Apollonio, F., Gaiani, M., & Bertacchi, G. (2020). Some reconstruction hypotheses of Leonardo's project for the tiburio of the Milan cathedral by using 3D digital models. *SCIRES-IT - SCIentific RESearch and Information Technology, 10*(1). https://doi.org/10.2423/i22394303v10n1p53

Gallerie degli Uffizi. (2021). Archivi Digitali delle Gallerie degli Uffizi | Le Gallerie degli Uffizi [Digital Catalogue]. Retrieved February 8, 2021, from Gallerie degli Uffizi website: https://www.uffizi.it/pagine/archivi-digitali

Gallerie d'Italia. (2021). Virtual tour Tiepolo [Virtual Museum]. Retrieved February 8, 2021, from Gallerie d'Italia—Virtual tour Tiepolo website: https://www.gallerieditalia.com/virtual-tour/tiepolo

Gelli, D., March, R., Salonia, P., & Vitulano, D. (2003). Surface analysis of stone materials integrating spatial data and computer vision techniques. *Journal of Cultural Heritage, 4*(2), 117–125. https://doi.org/10.1016/S1296-2074(03)00023-2

Google. (2021). Google Arts & Culture [Online service]. Retrieved February 9, 2021, from Google Arts & Culture website: https://artsandculture.google.com/

Guggenheim & Google. (2021). Solomon R. Guggenheim Museum and Foundation, New York, Stati Uniti—Google Arts & Culture [Cultural platform]. Retrieved February 15, 2021, from Google Arts & Culture website: https://artsandculture.google.com/partner/solomon-r-guggenheim-museum

Kersten, T. P., Tschirschwitz, F., & Deggim, S. (2017). DEVELOPMENT OF A VIRTUAL MUSEUM INCLUDING A 4D PRESENTATION OF BUILDING HISTORY IN VIRTUAL REALITY. *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, XLII-2/W3*, 361–367. https://doi.org/10.5194/isprs-archives-XLII-2-W3-361-2017

Khodulev, A., & Kopylov, E. (1996). *Physically Accurate Lighting Simulation*. 111–119. GraphiCon Scientific Society, RU.

Kowalski, W. (2009). *Ultraviolet germicidal irradiation handbook: UVGI for air and surface disinfection* (p. 501). Springer-Verlag. Scopus. https://doi.org/10.1007/978-3-642-01999-9

Louvre. (2019). Mona Lisa: Beyond the Glass [App store]. Retrieved February 15, 2021, from Viveport website: https://www.viveport.com/18d91af1-9fa5-4ec2-959b-4f8161064796

MACRO Museum. (2021). MACRO Museum [Museum Website]. Retrieved February 9, 2021, from MACRO Museum website: https://www.museomacro.it/extra/

Musei Vaticani. (2021). Musei Vaticani Catalogo Online [Digital Catalogue]. Retrieved February 8, 2021, from https://catalogo.museivaticani.va/index.php/Front/Index?lang=it_IT

Museo Egizio di Torino. (2021). Museo Egizio [Virtual Museum]. Retrieved February 9, 2021, from Museo Egizio website: https://museoegizio.it/en/

Nakamura, T., Yano, T., Watanabe, K., Ishii, Y., Ono, H., Tambata, I., ... Nakahata, Y. (2019). *360-degree transparent holographic screen display*. Presented at the ACM SIGGRAPH 2019 Emerging Technologies, SIGGRAPH 2019. Scopus. https://doi.org/10.1145/3305367.3327974

National Gallery & Google. (2021). The National Gallery, London, London, Regno Unito [Cultural platform]. Retrieved February 15, 2021, from Google Arts & Culture website: https://artsandculture.google.com/partner/the-national-gallery-london

Palace Museum. (2020). Virtual Tours|The Palace Museum [Virtual Museum]. Retrieved April 15, 2021, from The Palace Museum website: https://en.dpm.org.cn/multimedia/virutual/

Pascoal, S., Tallone, L., & Furtado, M. (2021). The Impact of COVID-19 on Cultural Tourism: Virtual Exhibitions, Technology and Innovation. *Smart Innovation, Systems and Technologies, 209*, 177–185. Scopus. https://doi.org/10.1007/978-981-33-4260-6_16

Pedersen, I., Gale, N., Mirza-Babaei, P., & Reid, S. (2017). More than Meets the Eye: The Benefits of Augmented Reality and Holographic Displays for Digital Cultural Heritage. *Journal on Computing and Cultural Heritage, 10*(2), 1–15. https://doi.org/10.1145/3051480

Pentagram Stiftung Foundation & Fondazione Giorgio Cini. (2021). Venice and American Studio Glass [Virtual Museum]. Retrieved February 9, 2021, from https://lestanzedelvetro.org/en/exhibitions/venice-and-american-studio-glass-2/

Pfarr-Harfst, M. (2020). Digital 2D and 3D visualisations as iconic epistemological models. *SCIRES-IT - SCIentific RESearch and Information Technology, 10*(1). https://doi.org/10.2423/i22394303v10n1p19

Rossi, M., Marini, D., & Rizzi, A. (2004). Methods and application for photorealistic rendering and lighting of ancient buildings. *Journal of Cultural Heritage, 5*(3), 291–300. https://doi.org/10.1016/j.culher.2003.12.004

Smithsonian. (2020). Virtual Tour | Smithsonian National Museum of Natural History [Virtual Museum]. Retrieved April 15, 2021, from Smithsonian National Museum of Natural History website: https://naturalhistory.si.edu/visit/virtual-tour

The Metropolitan Museum of Art & Google. (2021). The Metropolitan Museum of Art, New York City, Stati Uniti [Cultural platform]. Retrieved February 15, 2021, from Google Arts & Culture website: https://artsandculture.google.com/partner/the-metropolitan-museum-of-art

Valzano, V., & Mannino, K. (2020). Cultural Heritage communication and digital resources: Three examples from Messapian archaeology. *SCIRES-IT - SCIentific RESearch and Information Technology, 10*(2). https://doi.org/10.2423/i22394303v10n2p1

Valzano, V., Negro, F., & Lucarella, D. (2019). Otranto treasures in 3D. *SCIRES-IT - SCIentific RESearch and Information Technology, 9*(2). https://doi.org/10.2423/i22394303v9n2p17

Web3D Consortium. (2021). Web3D Consortium | Open Standards for Real-Time 3D Communication [Consortium website]. Retrieved February 19, 2021, from Web3D Consortium website: https://www.web3d.org/

WHO. (2020, March 11). WHO Director-General's opening remarks at the media briefing on COVID-19—11 March 2020 [Organization]. Retrieved February 15, 2021, from World Health Organization website: https://www.who.int/director-general/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19---11-march-2020