The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLVIII-M-2-2023
29th CIPA Symposium "Documenting, Understanding, Preserving Cultural Heritage:
Humanities and Digital Technologies for Shaping the Future", 25–30 June 2023, Florence, Italy

CULTURAL HERITAGE AND VIRTUAL REALITY: APPLICATION FOR VISUALIZATION OF HISTORICAL 3D REPRODUCTION

F. Bianconi[1], M. Filippucci[1], F. Cornacchini[1*], M. Meschini[1], C. Mommi[1]

[1] Department of Civil and Environmental Engineering, University of Perugia, 06125 Perugia, Italy.
fabio.bianconi@unipg.it, marco.filippucci@unipg.it, filippo.cornacchini@gmail.com, michela.meschini@yahoo.com, chiara.mommi@gmail.com

KEY WORDS: Historical simulation, Mobile App, Virtual Reality, Cultural Heritage, 3D model interaction, 3D reproduction.

ABSTRACT:

The research aims to preserve and support the historical memory of Perugia's Fontivegge district through an analysis and valorisation of the existing cultural heritage. The selected case study is represented by the original design of the station, ideated by architect Antonio Cipolla. In order to enhance this project, which was never realised, it was decided to exploit the three-dimensional reconstruction of the building, which had already been elaborated previously, to create a virtual reality experience, through users can visualize, explore and walk inside the build. The purpose is to consolidate the relationship between the historical memory of the city and its users, allowing them a new interaction with the space and bringing them to a deeper level of knowledge and understanding of the place they live. To increase the user base of this virtual experience, it was decided to create an application for mobile devices. The Unreal Engine software was selected for development, given the ease of exporting projects for the main mobile platforms (Android, iOS) and the specific functions for reading GPS data. In fact, the application only allows the exploration of the virtual scenario to real users of the place, so they physically visit it and thus can understand the differences and similarities between the real scenario and the virtual historical reconstruction. Once the geolocation is verified, the app provides the 3D model for a panoramic view of the build under examination and, subsequently, an immersive experience in which it is possible to freely navigate within the virtual reconstruction.

1. INTRODUCTION

In the contemporary historical scenario, characterised by the impulse of the digital transformation of which the smartphone is the symbol, the research proposes to use the new devices at the service of the visualisation of erased architecture, setting up a standardised methodological approach through the creation of a virtual reality application (Bianconi et al., 2020a; Bianconi et al., 2022; Checa and Bustillo, 2020; De Araujo Pistono et al., 2021; Ioannides et al., 2016; Larson, 2020; Shaw et al., 2014; Skamantzari and Georgopoulos, 2016; Smith et al., 2020) (Figure 1). A strong process of digitalization of cultural items and enriching informatiSon is developing in the field of cultural heritage (Bianconi et al., 2021; Curci and Fiorini, 2013; Puma, 2018), trying to identify new methodologies for preserving, analysing and communicating culture and places of interest (Calisi and Botta, 2022; Koebel et al., 2020; Paladini et al., 2019; Toffoletti, 2021).

Three-dimensional modelling for the architectural domain (Greengard, 2019; Münster et al., 2019) surpasses and enriches

Figure 1. Three-dimensional reconstruction of the original design of Perugia Fontivegge station.

* Corresponding author

the real, allowing the exploration of what "that could have been" through virtual scenarios (Calisi and Cianci, 2019; Hassani et al., 2015; Koebel et al., 2020; Tommasi, 2021).
Across simulation, the research aims to consolidate the relationship between the historical memory of the city and its digital visualisation (Bianconi and Filippucci, 2021; Hassani et al., 2015; Pallasmaa, 1994; Tommasi, 2021), enabling a new interaction with the space and bringing the user to a deeper level of knowledge and understanding (Francis et al., 2012; Jencks, 1969; Kim and Kaplan, 2004; Scholz and Smith, 2016).
This is, in the context of the collective and cultural memory of place, defined by Assman as "[...] a form of collective memory in that a number of people share cultural memory and in that it conveys to them a collective (i.e., cultural) identity" (Assmann, 2010).
In recent years, virtual reality (VR) technologies have undergone a significant evolution from being a niche curiosity to a driving force in the entertainment and culture industry. The ability to create immersive and interactive worlds has allowed this approach to make its way into many areas, including cultural heritage research. The investments and developments introduced by the two major competitors in this sector, Unity and Unreal Engine, have enabled the creation of increasingly detailed and immersive virtual reality experiences, providing features and scene components that facilitate the realization of scenarios very close to realism. This evolution has undoubtedly facilitated the diffusion in this sphere of approaches that can be traced back to gamification, that design technique that consists of using elements and mechanics of videogames in non-game contexts, in order to motivate and involve users in the execution of specific activities. In this context, the aim is to realize a Serious Game in a cultural context (Karahan and Gül, 2021; Larson, 2020; Robson et al., 2015; Vocaturo et al., 2019)) that, through three-dimensional representation, leads to an in-depth interpretation and reflection on the place (Karahan and Gül, 2021; Vocaturo et al., 2019).
By changing the knowledge of the space, through active involvement (Li and Huang, 2022), the users' attitude and interest in the built environment is changed (Aitamurto et al., 2021; Nikolaou et al., 2022).
Thus, it promotes a sense of place, which is linked to belonging through the value of history (Norberg-Schulz, 1980), its restoration and enhancement, seeking to stimulate active relationships between the place and the user who experiences it (Adler and Goggin, 2005; Rosenman et al., 2007; Sang et al., 2013) and the experience of place itself (Kim and Kaplan, 2004; Mendes et al., 2022).
This research is part of the collaboration between the Municipality of Perugia and the Department of Civil and Environmental Engineering of the University of Perugia (Bianconi and Filippucci, 2020, 2018) on the regeneration of the station area of Umbria's capital city. An inter-urban and regional transport interchange, the district presents numerous substantial problems, the result of settlement logics that are inattentive to the value of living (Gehl and Gemzøe, 2003) but also of a predominantly functionalist vision that renders this space aseptic to appropriation relations (Appadurai, 1996) (Figure 2). Due to its decline, it has been affected by various regeneration and restoration projects such as the 2015 National Urban Renewal Program. The University of Perugia has carried out several studies for the requalification of the area (Bianconi et al., 2020b, 2018; Bianconi et al., 2022), trying to investigate the driving meanings of the place in order to address urban regeneration. During these studies, a digital twin of the area was realized, in addition to 3D reproduction of historic buildings erased from collective memory such as the 1970s competition-winning residential complex by Tsuto Kimura, and the Perugina factory with its several transformations, in addition to the initial design of the station.
The previously mentioned plan (Piano, 2015) finds in research a stimulus to innovation (Bianconi et al., 2018), proposing the themes of representation as a solution to reactivate the relationships between the community and its places (Bauman, 2000) by associating public space with the provision of a welfare service for the person and the community.

Figure 2. Perugia Fontivegge rail station, current state.

2. METODOLOGY

The aim is to develop a replicable process of representation through VR of erased architecture, exploiting the potential offered by gaming software. It is intended to carry out a revaluation of the place, implementing the information available to the user and increasing the narrative of the urban space and its historical evolution, expanding communication and enabling a clearer and more complete reading.
Following a philological process, historical and archival research is conducted in order to obtain a complete knowledge of the architecture from spatial, textural and structural perspectives, in order to interpret and complete the project in case of missing parts. Starting with scans of archive images, the project is reproduced two-dimensionally in all its parts, and then three-dimensional modelling of the erased architecture is carried out.
Placing the model in the digital environment for VR app development, in this case Unreal Engine, becomes critical to preserve any previously defined data. The development house of the programme involved, Epic Games, provides the Datasmith plugin to carry out this process. Fundamental aspects such as materials and lighting, which support the immersiveness of the experience, are set according to concepts of photorealism and fidelity to reality.
It was selected to develop a mobile application (iOS - Android) so that it can be used by anyone with an average smartphone and maximize the dissemination and knowledge of the Cultural Heritage. This application is able to detect the geographical position of users to allow access to the dedicated virtual experience: when the position of the device enters a predefined area, a dual virtual experience is activated. The three-dimensional

model of the project can be investigated by rotating it and zooming in on certain details, while, subsequently, the immersive experience can be activated in which, again through the smartphone screen, users can freely navigate within the virtual model. The geographical constraint was imposed so that users physically visit the site and can understand the differences between the real scenario and the virtual historical reconstruction. It was not possible to place the classic QR codes on site as the station under consideration is private property. This condition becomes a virtue and therefore the position reading via GPS signal was implemented. Following the export of the app in apk, it was tested on site in order to receive feedbacks from the users (Figure 3).

Figure 3. Interaction with the app into the area of interest.

3. CASE STUDY

3.1 Modelling

First, a three-dimensional model was created using 3D Studio Max software, to reproduce as closely as possible the original design of the station, elaborated by Antonio Cipolla (Bianconi et al., 2022) (Figure 4).
The Unreal Engine development environment from Epic Games, was chosen for the creation of the mobile application. The three-dimensional model of the station was imported through Datasmith conversion plugin, which preserves all previously defined model infomations such as geometries, camera and surface normals (Figure 5).
Specific materials were assigned to the imported model and then the lights were set. Regarding the materials, they were made with textures with not too high resolution, in order to achieve a satisfactory graphic output, optimised for mobile devices, without heavily influencing the execution performance. As far as the lighting of the scene is concerned, it was chosen to proceed with a Global Illumination (GI) completely in real time, thus avoiding the 'baking' process of the lightmaps. Although this process usually slows down the execution of the app, by optimising the initial model and decreasing the model vertices, a smooth execution of the virtual experience is still achieved.

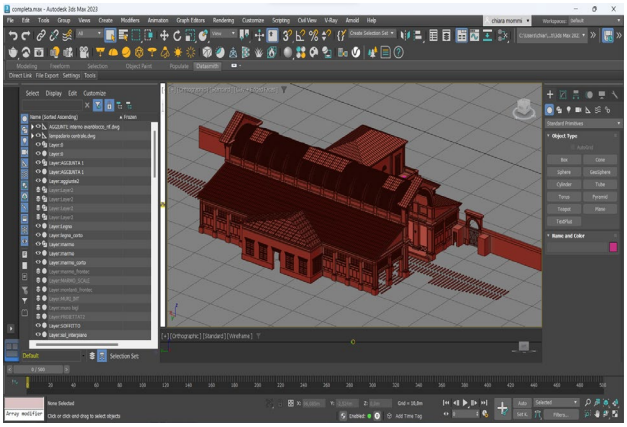

Figure 4. Visualization of the model into 3D Studio Max.

3.2 Programming

The programming of the application focused on three separate levels: the first represents the graphical interface of the app, where the user waits to enter the geolocalised area of interest; the second in which the user can interact with the model and view it from the outside; the third is represented by the immersive experience, inside it. All levels were programmed using the Blueprints Visual Scripting method, which is simpler and more intuitive than pure programming in the C++ language.
The first programming phase involved the part of the application needed to detect the geographical position of the device by exploiting the functions provided by Unreal Engine (EpicGames, 2023). When the recorded coordinates enter the set area of interest, a notification shows on the app's home screen that allows access to the dedicated in-depth study, in this case the station project by architect Antonio Cipolla, taking the user to the next level (Figure 6).

Figure 5. Import of the model into Unreal Engine.

As for the second level, once the notification is selected, the movements of the camera outside the model are set, which must follow the users' touch inputs on the screen: they will be able to rotate the frame by swiping their fingers on the screen and move the camera closer and further away through the classic "pinching" and "zooming" gestures (Figure 7).

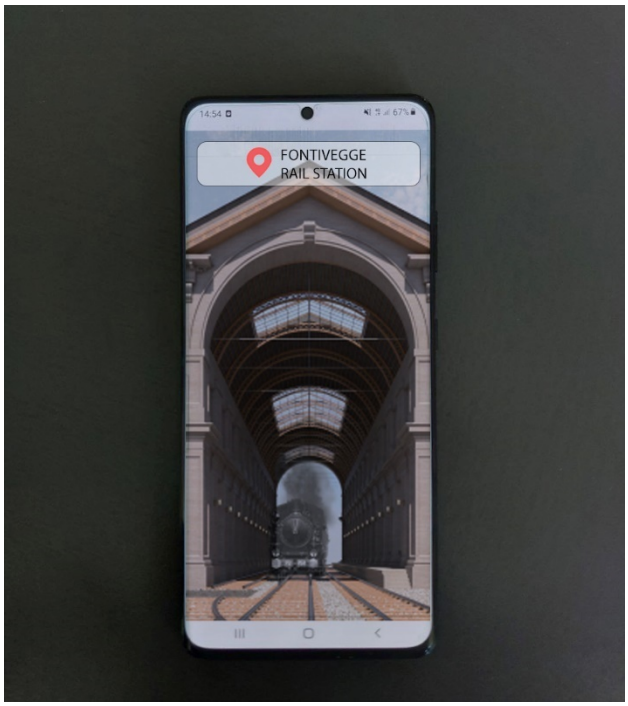

Figure 6. Notification of the app in the georeferenced area of interest.

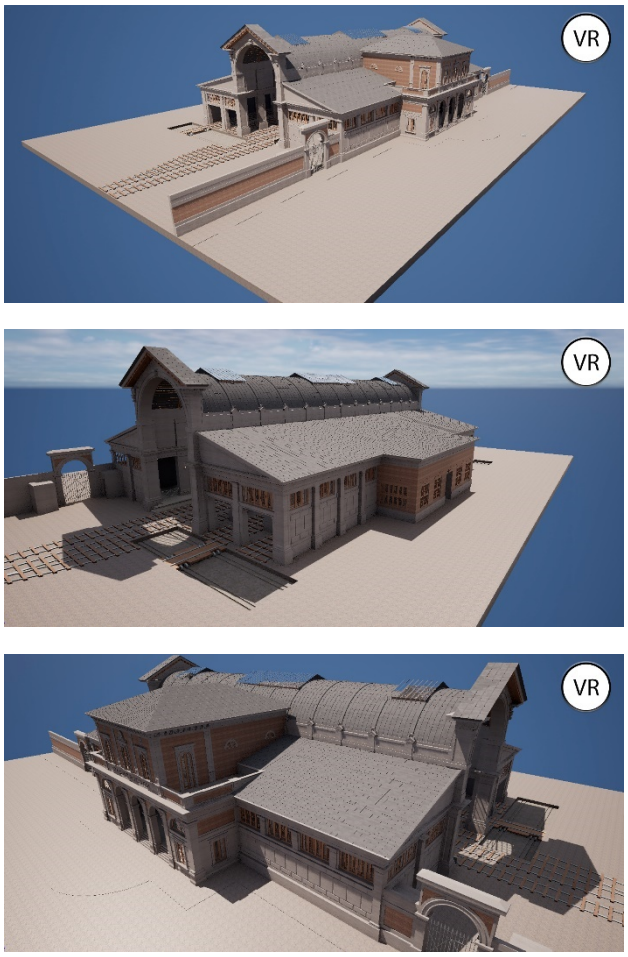

Figure 7. Visualisation of the model in the second level.

Through a button in the interface of the second level, it is possible to switch to the third, which is the one related to the immersive experience (Figure 8). The programming of this level involves the insertion into the scene of the Blueprint called “FirstPersonCharacter” already present in the Unreal Engine library and suitable for the first-person movement of a camera within a virtual space. In this level, it is important to activate the collisions of the model geometries in order to prevent users from interpenetrating with the virtual solid volumes. The creation of the collision volumes, which coincide with those of the geometry, is facilitated by modelling using 3D Studio Max and importing with Datasmith (Figure 9).
In order to prevent the user from moving away from the main scene, “blocking volumes” were inserted along the perimeter of the model's terrain. In addition, virtual touch controllers, pre-loaded in the Unreal Engine software, were activated to allow user movement during the virtual experience (Figure 10).

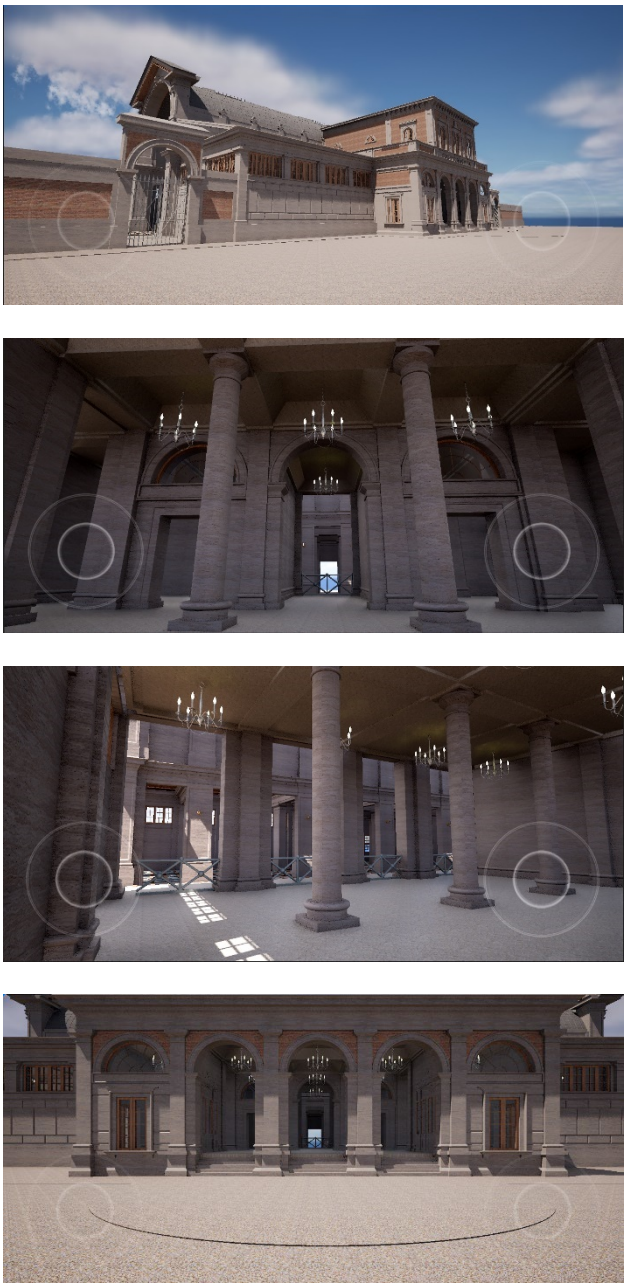

Figure 8. Visualisation of the model in the third level.

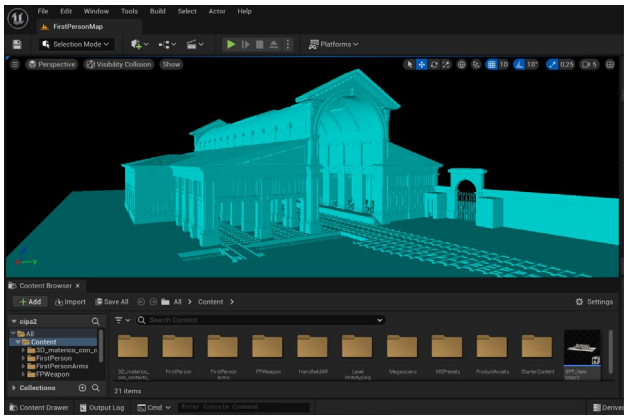

Figure 9. Collision visualization in Unreal Engine.

3.3 Exporting

For exporting the application, in this first phase of testing, Android is chosen as the execution platform, due to its large diffusion: in 2022, in fact, 75% of Italian smartphones use devices with this operating system (Laricchia, 2022). To execute this, “project packaging” must be done, which ensures that all code and content is up-to-date and in the correct format, and then later runs on the desired target platform (Android) by creating an apk file that can be installed and opened directly on smartphones.

4. CONCLUSION

The application was tested on a small group of users, who respond positively to the experience. In particular, the idea of visiting a historical project that had never been built and to learn its peculiarities through an interactive and immersive scenario was appreciated, being able to explore the three-dimensional model in detail, observing the details and features of the building closely, transforming the intangible into the tangible (Picon, 2010; Selmanović et al., 2020). In addition, the use of advanced technologies as a tool for cultural enrichment about architectural history has been particularly appreciated, which can well replace or work alongside traditional visits to museums or historical sites (Anderson et al., 2010; Benjamin, 1969; Carpentier, 2011; Hampton, 2016; Mortara et al., 2014). Lastly, the constraint of being in close proximity to the site that would host the project allowed for a comparison with the current station, therefore analyzing the evolution of past ideas and giving visitors a new perspective on the history of architecture and design and a renewed sense of place (Corallo et al., 2019).

The innovations introduced by this new approach, in fact, consist specifically in the use of GPS signal to geolocate users, without having to use more invasive methods. The exploitation of smartphones to engage users is another strength of this strategy, as it enables its use by the majority of users who experience the place.

At this stage of development, the app is presented in a fairly stripped-down form, offering the simple visualization of the 3D model, and with only the station design available to users. There is, however, a wide variety of cultural material ready to be descrived through VR representation. Within the research conducted by the University of Perugia, as mentioned previously, projects related to Tsuto Kimura's residential complex and to the transformations of the Perugina factory, to date demolished and replaced with Aldo Rossi's famous Piazza del Bacio complex project, have been modeled. One of the next steps is to expand with these projects the availability of erased architecture that can be visited through this application. In addition, the virtual experience could be enriched with informational popups within the exploration or with an appropriately designed storytelling to guide the user through the exploration, creating a narrative path to help him or her better understand the history of the project, how it was conceived, who its author was, and why it was never built (Banfi et al., 2021; Filippucci, 2021).

Figure 10. Interaction with the app in the third level.

REFERENCES

Adler, R.P., Goggin, J., 2005. What Do We Mean By "Civic Engagement"? *J. Transform. Educ.* 3, 236–253. https://doi.org/10.1177/1541344605276792

Aitamurto, T., Won, A.S., Sakshuwong, S., Kim, B., Sadeghi, Y., Stein, K., Royal, P.G., Kircos, C.L., 2021. From FOMO to JOMO: Examining the fear and joy of missing out and presence in a 360 video viewing experience, in: Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems. Yokohama, pp. 1–14.

Anderson, E.F., McLoughlin, L., Liarokapis, F., Peters, C., Petridis, P., De Freitas, S., 2010. Developing serious games for cultural heritage: a state-of-the-art review. *Virtual Real.* 14, 255–275.

Appadurai, A., 1996. *Modernity at large: cultural dimensions of globalization*. University of Minnesota Press, Minneapolis.

Assmann, J., 2010. Communicative and Cultural Memory, in: Erll, A., Nünning, A. (Eds.), An International and Interdisciplinary Handbook. De Gruyter, Berlin, New York, pp. 109–118. https://doi.org/doi:10.1515/9783110207262.2.109

Banfi, F., Bolognesi, C.M., Bonini, J.A., Mandelli, A., 2021. the Virtual Historical Reconstruction of the Cerchia Dei Navigli of Milan: From Historical Archives, 3D Survey and Hbim To the Virtual Visual Storytelling. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci.* XLVI-M-1–2, 39–46. https://doi.org/10.5194/isprs-archives-xlvi-m-1-2021-39-2021

Bauman, Z., 2000. *Liquid modernity*. Polity Press, Cambridge.

Benjamin, W., 1969. *The work of art in the age of mechanical reproduction*. Schocken Books, New York.

Bianconi, F., Clemente, M., Filippucci, M., Salvati, L., 2018. Re-sewing the Urban Periphery. A Green Strategy for Fontivegge District in Perugia. *TEMA* 11, 107–118.

Bianconi, F., Filippucci, M., 2021. *Iperografie amerine*. Maggioli spa, Santarcangelo di Romagna.

Bianconi, F., Filippucci, M., 2020. *Lineamenta*. Maggioli, Santarcangelo di Romagna (RN).

Bianconi, F., Filippucci, M., 2018. Rappresentazione, percezione, progetto. Il ruolo dell'Università per Perugia città smart, in: Rappresentazione Materiale/Immateriale - Drawing as (in) Tangible. Gangemi, pp. 37–48.

Bianconi, F., Filippucci, M., Anniboletti, L., Caponi, T., 2021. Eredità archeologiche. Linguaggi, distanze, tecnologie dal rilievo classico ai modelli digitali immersivi, in: CONNETTERE: Un Disegno per Annodare e Tessere - CONNECTING: Drawing for Weaving Relationships. FrancoAngeli, pp. 2062–2091.

Bianconi, F., Filippucci, M., Cornacchini, F., 2020a. Play and transform the city. *sciresit.it* 2, 141–158. https://doi.org/10.2423/i22394303v10n2p141

Bianconi, Fabio, Filippucci, M., Mommi, C., 2022. the Seduction of the Simulation. 3D Modelling and Storytelling of Unrealized Perugia Rail Station. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci. - ISPRS Arch.* 43, 1145–1152. https://doi.org/10.5194/isprs-archives-XLIII-B2-2022-1145-2022

Bianconi, F., Filippucci, M., Seccaroni, M., 2020b. Il rilievo digitale della percezione. Reinterpretazioni parametriche dell'impatto dell'ambiente sull'uomo. The digital survey of perception. Parametrics reinterpentations of the impact of the environment on men., in: 3d modeling - data modeling & management for aeco industry. dei s.r.l. tipografia del genio civile, Roma, pp. 228–243.

Calisi, D., Botta, S., 2022. Virtual Reality and Captured Reality for Cultural Landscape Communication. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci. - ISPRS Arch.* 46, 113–120. https://doi.org/10.5194/isprs-archives-XLVI-2-W1-2022-113-2022

Calisi, D., Cianci, M.G., 2019. La realtà virtuale immersiva per la conoscenza del patrimonio culturale: il quartiere alessandrino a Roma., in: Patrimoni in Divenire. Conoscere, Valorizzare, Abitare. Gangemi Editore, Roma, pp. 1357–1366.

Carpentier, N., 2011. *Media and participation : a site of ideological-democratic struggle*. Intellect, Bristol.

Checa, D., Bustillo, A., 2020. A review of immersive virtual reality serious games to enhance learning and training. *Multimed. Tools Appl.* 79, 5501–5527. https://doi.org/10.1007/s11042-019-08348-9

Corallo, A., Esposito, M., Marra, M., Pascarelli, C., 2019. Transmedia digital storytelling for cultural heritage visiting enhanced experience, in: Augmented Reality, Virtual Reality, and Computer Graphics: 6th International Conference, AVR 2019, Santa Maria Al Bagno, Italy, June 24–27, 2019, Proceedings, Part II 6. Springer, pp. 221–229.

Curci, A., Fiorini, A., 2013. Documentare l'archeologia 3.0. Atti del Workshop (Bologna, Alma Mater Studiorum Università di Bologna, 23 aprile 2013). *Archeol. e Calc.*

De Araujo Pistono, A., Santos, A., Baptista, R.J.V., 2021. Serious games: Review of methodologies and games engines for their development. *ieeexplore.ieee.org*.

EpicGames, 2023. Location [WWW Document]. URL https://docs.unrealengine.com/5.1/en-US/BlueprintAPI/Services/Mobile/Location/

Filippucci, M., 2021. Medusa and Pegasus: The Landscape in the Age of Its Technical Non-reprodution, in: Digital Draw Connections. Representing Complexity and Contradiction in Landscape. Springer, Cham, pp. 57–110. https://doi.org/10.1007/978-3-030-59743-6

Francis, J., Giles-Corti, B., Wood, L., Knuiman, M., 2012. Creating sense of community: The role of public space. *J. Environ. Psychol.* 4, 401–409. https://doi.org/10.1016/j.jenvp.2012.07.002

Gehl, J., Gemzøe, L., 2003. *New city spaces*. The Danish Architectural Press, Copenhagen.

Greengard, S., 2019. *Virtual Reality*, The MIT Press Essential Knowledge series. MIT Press, Cambridge.

Hampton, K.N., 2016. Persistent and Pervasive Community. *Am. Behav. Sci.* 60, 101–124. https://doi.org/10.1177/0002764215601714

Hassani, F., Studies, W.H., Process, C., Technology, D., Heritage, C., 2015. Documentation of cultural heritage techniques , potentials and constraints xl, 207–214. https://doi.org/10.5194/isprsarchives-XL-5-W7-207-2015

Ioannides, M., Fink, E., Moropoulou, A., Hagedorn-Saupe, M., Fresa, A., Liestøl, G., Rajcic, V., Grussenmeyer, P., 2016. *Digital heritage : progress in cultural heritage: documentation, preservation, and protection: 6th International Conference, EuroMed 2016, Nicosia, Cyprus, October 31-November 5, 2016, Proceedings. Part II.* Springer.

Jencks, C., 1969. *Meaning in architecture.* The Cresset Press, London.

Karahan, S., Gül, L.F., 2021. Mapping current trends on gamification of cultural heritage, in: Game+ Design Education: Proceedings of PUDCAD 2020. Springer, pp. 281–293.

Kim, J., Kaplan, R., 2004. Physical and Psychological Factors in Sense of Community. *Environ. Behav.* 36, 313–340. https://doi.org/10.1177/0013916503260236

Koebel, K., Agotai, D., Çöltekin, A., 2020. Exploring cultural heritage collections in immersive analytics: Challenges, benefits, and a case study using virtual reality. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci. - ISPRS Arch.* 43, 599–606. https://doi.org/10.5194/isprs-archives-XLIII-B4-2020-599-2020

Laricchia, F., 2022. Market share held by smartphone OS in Italy 2019-2022 [WWW Document]. URL https://www.statista.com/statistics/260422/market-share-held-by-smartphone-operating-systems-in-italy/

Larson, K., 2020. Serious Games and Gamification in the Corporate Training Environment: a Literature Review. *TechTrends*. https://doi.org/10.1007/s11528-019-00446-7

Li, W., Huang, X., 2022. The Interactive Design and User Experience of Virtual Museums: Case Study of the Virtual Palace Museum, in: Cross-Cultural Design. Applications in Learning, Arts, Cultural Heritage, Creative Industries, and Virtual Reality: 14th International Conference, CCD 2022, Held as Part of the 24th HCI International Conference, HCII 2022, Virtual Event, June 26–July 1, 2. Springer, pp. 400–409.

Mendes, L.O., Cunha, L.R., Mendes, R.S., 2022. Popularity of Video Games and Collective Memory. *Entropy* 24. https://doi.org/10.3390/e24070860

Mortara, M., Catalano, C.E., Bellotti, F., Fiucci, G., Houry-Panchetti, M., Petridis, P., 2014. Learning cultural heritage by serious games. *J. Cult. Herit.* 15, 318–325.

Münster, S., Apollonio, F.I., Bell, P., Kuroczynski, P., DI Lenardo, I., Rinaudo, F., Tamborrino, R., 2019. Digital Cultural Heritage Meets Digital Humanities. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci. - ISPRS Arch.* 42, 813–820. https://doi.org/10.5194/isprs-archives-XLII-2-W15-813-2019

Nikolaou, A., Schwabe, A., Boomgaarden, H., 2022. Changing social attitudes with virtual reality: a systematic review and meta-analysis. *Ann. Int. Commun. Assoc.* 46, 30–61.

Norberg-Schulz, C., 1980. *Genius Loci. Towards a phenomenology of architecture*. Rizzoli, New York.

Paladini, A., Dhanda, A., Ortiz, M.R., Weigert, A., Nofal, E., Min, A., Gyi, M., Su, S., Balen, K. Van, Santana, M., Museum, N., 2019. Impact of virtual reality experience on accessibility of cultural XLII, 8–10.

Pallasmaa, J., 1994. Identity, intimacy and domicile. Notes on the phenomenology of home. *Finish Archit. Rev.* 1–16.

Piano, R., 2015. Renzo Piano: rammendo e rigenerazione urbana per il nuovo rinascimento. *Ingenio*.

Picon, A., 2010. *Digital culture in architecture*. Birkhäuser, Basel.

Puma, P., 2018. Multidisciplinary experiences of virtual heritage for the documentation of architecture and archaeology within the DigitCH group - Digital cultural heritage group, in: Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics). pp. 242–252. https://doi.org/10.1007/978-3-030-01765-1_27

Robson, K., Plangger, K., Kietzmann, J.H., McCarthy, I., Pitt, L., 2015. Is it all a game? Understanding the principles of gamification. *Bus. Horiz.* 58, 411–420.

Rosenman, M.A., Smith, G., Maher, M.L., Ding, L., Marchant, D., 2007. Multidisciplinary collaborative design in virtual environments. *Autom. Constr.* 16, 37–44. https://doi.org/10.1016/j.autcon.2005.10.007

Sang, M.K., Won, S.C., Yong, G.J., 2013. Usability Principles for Augmented Reality Applications in a Smartphone Environment. *Int. J. Hum. Comput. Interact.* 29, 501–515.

Scholz, J., Smith, A.N., 2016. Augmented reality: Designing immersive experiences that maximize consumer engagement. *Bus. Horiz.* 59, 149–161. https://doi.org/10.1016/j.bushor.2015.10.003

Selmanović, E., Rizvic, S., Harvey, C., Boskovic, D., Hulusic, V., Chahin, M., Sljivo, S., 2020. Improving accessibility to intangible cultural heritage preservation using virtual reality. *J. Comput. Cult. Herit.* 13, 1–19.

Shaw, J., Kenderdine, S., Hart, T., 2014. mARChive [WWW Document]. URL http://www.icinema.unsw.edu.au/projects/marchive/project-overview

Skamantzari, M., Georgopoulos, A., 2016. 3d visualization for virtual museum development. *Int. Arch. Photogramm. Remote*

Sens. Spat. Inf. Sci. XLI-B5, 961–968. https://doi.org/10.5194/isprs-archives-xli-b5-961-2016

Smith, J., Sears, N., Taylor, B., Johnson, M., 2020. Serious games for serious crises: Reflections from an infectious disease outbreak matrix game. *Global. Health* 16. https://doi.org/10.1186/s12992-020-00547-6

Toffoletti, I. (Ed.), 2021. *Chiusi per Covid aperti per cultura. Musei e comunicazione digitale.* Gangemi, Roma.

Tommasi, C., 2021. Modalities of valorisation and promotion of cultural heritage through ict : adding new milestones to the “ standard ” practice XLVI, 745–752.

Vocaturo, E., Zumpano, E., Caroprese, L., Pagliuso, S.M., Lappano, D., 2019. Educational Games for Cultural Heritage., in: VIPERC@ IRCDL. pp. 95–106.