Protagonists of their own Discovery: Engaging the European Public with Florentine Heritage

The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLVIII-M-9-2025
30th CIPA Symposium "Heritage Conservation from Bits:
From Digital Documentation to Data-driven Heritage Conservation", 25–29 August 2025, Seoul, Republic of Korea

Protagonists of their own Discovery: Engaging the European Public with Florentine Heritage

Daniel Mangano [1], Scott McAvoy [2,5], George Bent [3], Maurizio Seracini [4], David Pfaff [3], Aviral Agarwal [2], Falko Kuester [2]

[1] Politecnico di Torino, Dipartimento di Architettura e Design, Turin, Italy - daniel.mangano@polito.it
[2] Cultural Heritage Engineering Initiative, University of California San Diego (smcavoy, aviral, fkuester)@ucsd.edu
[3] Washington and Lee University – (bentg, dpfaff)@wlu.edu
[4] Editech - seracini@editech.com
[5] OpenHeritage3D - smcavoy@oh3d.org

Keywords: Documentation, Augmented Reality, Extended Reality, Co-creation, Cultural Heritage.

Abstract
Common diagnostic imaging technologies (like thermography, radiography, ground penetrating radar, high resolution 3d mapping) have a largely untapped potential to inform the public understanding and interpretation of historic sites. In historic places of constant use, the resulting compounded architectural tectonics resulting from continuous change over time can be difficult to interpret, even for experts. This paper incorporates several highly visible use cases within Florence, Italy to demonstrate the potential for data gathered from diagnostic imaging to be overlaid within a publicly available augmented reality experience to create useful tools for heritage communication and engagement within the hidden layers of a built environment. We provide methodologies for the translation of several key data types into interactive media and elaborate upon the state of the art concerning interactive location-based augmented reality toolkits and platforms within the context of cultural heritage communication.

1. Introduction

To create a true sense of participation, the experience of co-creation with cultural heritage is a central function in instilling a sense of confidence that invites the public to develop their own understanding of cultural heritage through a non-didactic approach. The public will be engaged in the act of interpretation and personal discovery rather than passively viewing an experience. They will proceed to co-author and co-curate their own experiences playing the role of the protagonist rather than merely as witness.

Although the technologies employed here are relatively new, the goal of this endeavor is hundreds of years old. The artistic tradition of *Capriccio* serves as a historical precedent for this type of public engagement with cultural heritage. Heavily associated with the grand tour of the 18th century, the systematic depiction of Italy's cultural monuments is perhaps one of the first movements in western art motivated by the desire to represent pictorial reconstructions of heritage sites. Many of the paintings and prints developed in this period catered specifically to the desires of tourists who wanted to have a sense of ownership, primarily by purchasing these images to bring home as souvenirs which represented the historic sites that they had traveled long distances to see (Campione, 2019). These images famously portrayed fantastical urbanscapes composed of collaged elevations of well-known sites in whimsical compositions that documented historic sites in views that appealed to the imagination of viewers in the places where these works were displayed. These images diffused an understanding of classical antiquity and an appetite to consume previously inaccessible imagery and themes with a wider public who lacked the means to travel. Despite the fact the places in capriccio images represented sites of antiquity in a way they never existed, they served to spark curiosity and engagement with history through diverse audiences (Dethier et al., 2014). Just as these novel images instilled a sense of curiosity and agency in the public by permitting them to layer their own interpretations of sites, our proposed approach allows the public to access visual dimensions rarely seen to draw new conclusions becoming the protagonist to new revelations regarding cultural heritage.

This paper builds upon previous work performed by the ARtifact project (Vanoni 2012) and 3D data collected through various conservation efforts performed in partnership with the Cultural Heritage Engineering Initiative and the Florence as it Was project (Bent, n.d.). The types of information made available in this project is information that has been critical to the stewardship and conservation of the sites involved. Scientific investigations, employing thermal images (Figure 1), LiDAR scans, and other multi-spectral imaging sensors have provided critical insight used to make key conservation decisions. Positioning this data as an interpretation of the site tells a fundamentally different story than a reconstruction, it allows the public to see and interpret the physical conditions of the site (Lercari et al., 2018). This paper will discuss the role of diagnostic data and documentation as foundational elements of public engagement. These data, which reveal hidden elements of Florentine heritage, prompt users to engage in the interpretation of anomalies, and, we hope, create a personal connection to the works by revealing their vulnerabilities (Dieck et al., 2017).

2. Related Work

In a meta-study analyzing over 1200 articles related to XR in cultural heritage, the authors demonstrated that Italy is the main contributor to the field (Boboc et al., 2022). Many of these projects focus on the paragon of the past version of a heritage site in relation to how it is today. VR and AR reconstructions of digitally projected spaces in which a visitor can inhabit and walk around, exploring on their own course are powerful and successful strategies to inject agency within cultural heritage sites. However these interventions show the reconstructed past in an idealized and objective way leaving little room for questioning or interpretation from the visitor, they maintain the format of a spectacle viewed by an audience. The intention of this project is not to show a reconstruction of the past conditions, rather information that elaborates on the unseen elements of the site that are revelatory of a larger story and invite the visitor to question and engage with the past rather than being instructed.

The state of the art in XR experiences in cultural heritage sites tends to be a wholly or semi-immersive reconstruction which takes the visitor through a reconstruction of the site, annotating and extrapolating key features of the site, achieving a mixture of live views and geotagged digital elements that appear within a

preprogrammed guided sequence. Two noteworthy augmented and virtual reality experiences representing a touchstone for the state of the art in this vein of extended reality for cultural heritage sites are found in the Duomo di Milano and the Domus Aurea in Rome. In the Duomo di Milano the visitor, wearing augmented reality glasses which blend their own vision with XR assets is prompted to move about the site to fixed points in space to initiate a segment of the tour. These experiences may also be totally immersive, such as a fully interactive reconstruction of the church's baptistry within its archaeological excavation area. This experience is a sophisticated implementation of a blending augmented reality and fully immersive virtual reality, however, maintains little room for the visitor to participate in any more significant way than a viewer (ArtGlass, 2023). Similarly, a visit to the Domus Aurea in Rome from the 22nd of June 2023 to the 14th of January 2024 concluded with a fully immersive virtual reality film, showing the reconstruction of the Domus Aurea and its later re-discovery in the early renaissance. The film requires the visitor to be seated while they observe with minimal movement, head turning permitted to look around in the environment, while an orchestrated immersive video is played (katatexilux, 2017). Similarly in this case the visitor is a spectator to an experience with no space left for dialogue.

These two forms of XR applications in cultural heritage provide engaging experiences for cultural heritage but maintain the spectator spectacle dynamic in which a curated experience is being observed and there is no space for a dialogue with the visitor outside of a didactic exchange. The course, the content, the engagement is all pre-planned and curated with the visitor only needing to follow the provided instructions. This paper argues the potential for this technology which can be expanded are the opportunities for the creation of discursive encounters programmed by the user's curiosity.

In Florence, specifically, several XR projects have been completed helping to provide visitors a more engaging and interactive means to discover heritage. The Hidden Florence project harnesses GPS tracking technology on mobile devices, enabling tourists to view their own position in real time in relation to an annotated map from 1584 (Nevola et al., 2022). In this way the user is able to easily contextualize their own position in relation to a lost past. This however is a layered map which incorporates historic maps with contemporary gps data and does not include site specific or reality extended installations that are mapped onto landmarks. In the church of Santa Croce there is an XR app incorporating a virtual tour, annotating architectural features and artwork within the church and museum (Gruppo TIM, 2023). This app, following a trend started at the introduction of 5G wireless technology to advertise services through the development and dissemination of XR apps in heritage sites, uses image recognition without tracking. An object is recognized within a mobile device window, and a digital asset floats in space as the screen moves around, sometimes showing images of the piece from alternate angles outside of physical reach.

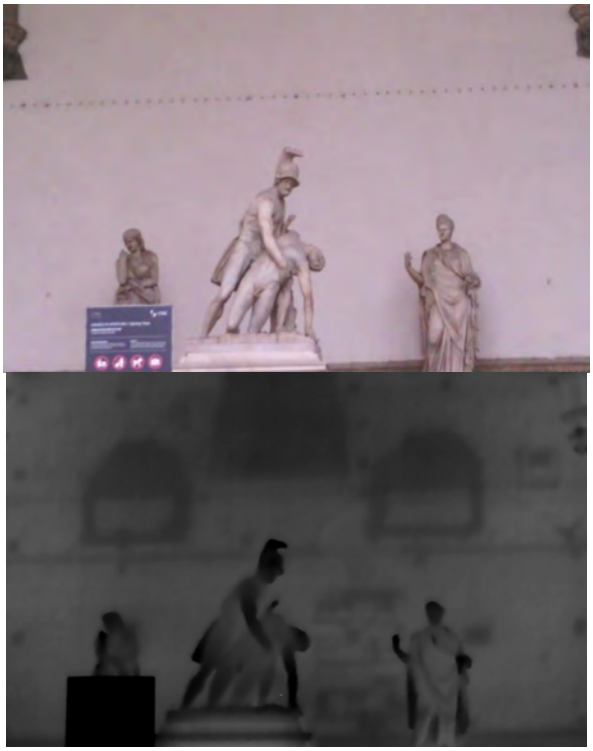

Figure 1. Photograph and corresponding thermographic image revealing structural makeup of wall behind the Loggia dei Lanzi.

The first phase of this approach is an exploration of the types of documentation methods that can reveal otherwise invisible details within, and beneath publicly accessible spaces and the kinds of information produced by this documentation (Kuester et al., 2023). This will be followed by a discussion of how this information can be adapted with location-based augmented reality toolkits to create an informative experience that is accessible to the millions of visitors who cross the piazza annually (*ARKit*, n.d.; *OurWorlds*, n.d.).

3. Discovering the Past in Piazza della Signoria

Florence’s Piazza della Signoria has been the center of the evolution of the city between many periods, from the Etruscans and Romans in antiquity, to the Republican period of the Middle Ages, to the Medicean Duchy of the Renaissance, and on into the modern era. Each of these periods have brought significant architectural evolution, leaving a complex stratification of remains incorporated into what is now the piazza encountered by thousands of tourists each day. This constant evolutionary change is in itself a challenge to interpret to the public due to the inaccessibility of many of the subterranean and architectural remnants that cannot be seen or understood without sophisticated methods of documentation and presentation that are normally out of the public’s reach (*Florence and Its Province: The Archaeological Locations*, n.d.; Salvini & Faralli, n.d.; Trachtenberg, 2010).

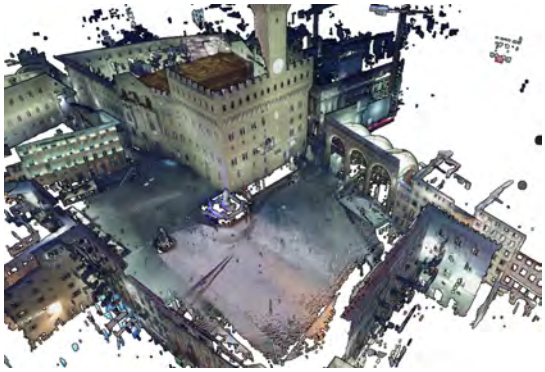

Figure 2. Terrestrial lidar data showing the Piazza della Signoria (Kuester 2015).

This project incorporates digital layers exposing unseen details for five sites within the Piazza della Signoria. Florentina and the Medieval Palazzo Vecchio constructed above its remains, the foundations of a previous neighborhood that existed on the piazza prior to the Ghibelline/Guelph conflicts of the 13th century that resulted in its destruction, the familial compound of the powerful Uberti family, the Romanesque church of S. Pier Scheraggio (figure 3) that abutted the Palazzo Vecchio in the 14th century, but which was demolished in the 16th to make way for the north edge of the Uffizi galleries: its columns, altar wall, and foundations are still visible today (figure 4)(Hardie, 1965; Trachtenberg, 2010) and the Palazzo Bombici that consumed within its walls the now-lost medieval church of St. Romulo (figure 5) which is, without imaging equipment, invisible to the public (figure 6).

Figure 3. Photograph showing the remains of Chiesa S. Pier Scheraggio

Figure 4. Current interpretive signage in piazza della signoria compared with a rendering placing a model of a roman theatre in the position where it would have been in the piazza.

The theatre of roman Florentia was excavated in several archaeological campaigns from 1974 to 1997, although the presence of the theatre was known during the construction of the super positioned Palazzo Vecchio. Based on the assessment of the archaeological remains uncovered it was determined that the theatre was most likely an example of the Etruscan Hellenic theatre design (Giorgi, 2015).

Figure 5. Bernardo Bellotto Firenze, Piazza della Signoria Budapest, Museo di Belle Art, zoom on the church of St. Romolo

Figure 6. Original triangular peaked facade of San Romolo revealed with thermography in XR app.

4. Examples in Imaging for Cultural Heritage Conservation and Communication

We have incorporated a number of individual artworks throughout the city of Florence in order to engage users in understanding structural properties of famous artworks and the conservation challenges they entail. By presenting layers of diagnostic data, we hope to promote data literacy, engage users over the interpretation of anomalies, and foster an emotional connection through the communication of environmental risks and their impacts on heritage objects and structures.

4.1 Tornabuoni Chapel, Church of Santa Maria Novella

The Tornabuoni chapel is the main apse behind the altar of the storied church of Santa Maria Novella. The 23-meter-tall chapel has three walls covered in frescoes created by Ghirlandaio in the late 15th century. These frescos are known worldwide for their beauty and quality. In 2025 a thermographic investigation (McAvoy 2025), revealed cracks in the walls behind the frescos, contributing to cracking and detachments on the surface. The results of this investigation are shared in two layers viewable in XR (figure 7). The deviation map shows a planar deviation analysis, pointing to potential detachments based on geometries extracted from terrestrial LiDAR. A Thermographic layer reveals cracks, and shows clearly filled in windows, a doorway, and scaffolding indentations, which are otherwise hidden from view.

Figure 7. Geometric deviation map, Tornabuoni Chapel Santa Maria Novella

As part of the same investigation, a high resolution structured light scan was performed on the 2nd panel of the western wall, portraying the Nativity of Mary. This model shows, at 0.5 mm resolution, the fine cracks, discolorations, and subtle geometries of the fresco (figure 8). Visitors can be forgiven for thinking that the surface of the fresco seems flat. Through the XR overlay of a surface deviation and slope maps, tracing incisions, moundings of plaster, and metallic inlays are made clearly visible behind the colored surface, giving important insight into the process of fresco painting.

Figure 8. Santa Maria Novella Tornabuoni Chapel - west wall panel 2, Nativity of Mary.Visible layer above, slope and deviation map below.

4.2 Strozzi Mantova Chapel, Santa Maria Novella

This chapel’s northern wall was painted by Orcagna in 1349. It depicts Hell as imagined from Dante’s inferno. A series of floods and restoration efforts have left the wall in a precarious state. The fresco had been removed from the wall, in a conservation effort,

and reapplied to a secondary surface. Over time that surface deformed, likely damaged by moisture and sagging under its own weight like draped cloth. Using geometry extracted by a LiDAR campaign (Bent, n.d.) the surface deviation was calculated and rendered (McAvoy et al., 2024), and now made available as XR layers (figure 9). As the fresco is currently undergoing further conservation efforts, we hope to generate additional images to show the resultant changes.

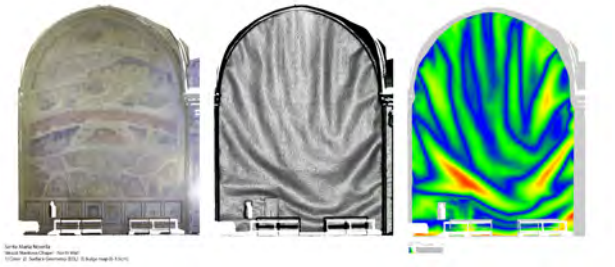

Figure 9. Strozzi Mantova Chapel in Church of Santa Maria Novella, slope and deformation map.

4.3 Da Vinci’s Adoration of the Magi

This application re-incorporates imagery and data relating to investigations performed by Professor Maurizio Seracini on Da Vinci’s Adoration of the Magi, prior to its restoration in 2012. These images, initially made available through the ARtifact project (Vanoni et al., 2012) enabled users to navigate and overlay 6 different data layers, including an infrared (IR) mosaic revealing original sketches below the visible paint layer, an ultraviolet (UV) layer showing differences in natural materials and highlighting previous restoration efforts, and xray images revealing the foundational wooden planks and iron fittings upon which the painting was created (figure 10).

Figure 10. Hyperspectral layers from Seracini’s investigation of Da Vinci’s Adoration of the Magi, visible, infrared, ultraviolet, and xray layers.

4.4 The Battle of Marciano, Palazzo Vecchio

In the Palazzo Vecchio’s Hall of the 500 is a painting by Giorgio Vasari between 1563 and 1565, which has been the subject of multiple investigations over the last few decades. It is hypothesized that this painting covers a lost Da Vinci painting called the Battle of Anghiari, the story of which is told on a video kiosk below. A thermogram from investigations carried out by Professor Maurizio Seracini in 2012 shows the structure behind the image (figure 10) and the layer is made available to users in XR. (figure 11). It is our hope to add additional data in the future, including radar cross sections.

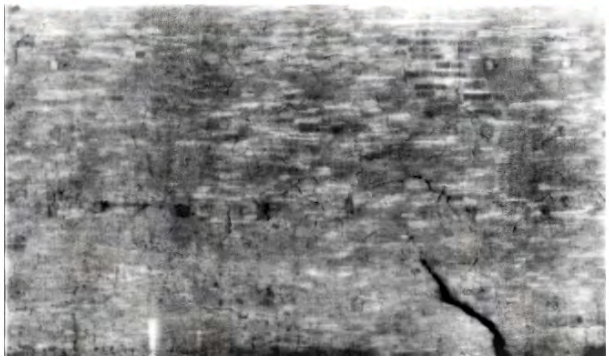

Figure 10. thermogram showing structural materials behind Vasari’s Battle of Marciano

Figure 11. Thermal overlay on Vasari’s Battle of Marciano, image courtesy of Dr. Valentina Bonora

5. Methodology

5.1 Systems Development

In this project we need to append digital objects to featureful paintings and built environments. We decided to develop the app using the Vuforia AR suite (2025), integrated with the Unity engine (2025) just as we had done in the previous iteration of the project some 12 years ago. Though this has the downside of complicating the development environments and requires the creation of different outputs compiled for different devices. The Vuforia system includes a number of alternate methods for real world tracking and interaction, including:

- **Image targets:** Are optimized RGB photos of real-world subjects which are mapped to planar objects in 3D space and recognized and tracked by the XR system.
- **Model targets**: tracking digital assets to a 3D object. This feature functions as a sort of multi-image target, with image features tracked in relation to each other across a 3d space, rather than tracking the geometry itself.
- **Georeferenced area targets:** using the mobile device’s GPS position to trigger zones of interactions. Unfortunately, our informal tests within the Piazza della Signoria resulted in highly inaccurate GPS readings, sometimes off by more than 30 meters. This kind of error is unfortunately common and inconsistent depending on location. Even leading mapping systems (Google, 2024) will often show these demonstrations from a distance which anticipates this kind of error.
- **Ground plane targets:** tracking assets against a flat plane. This particular method, locking a digital object to a flat surface, whether ground or tabletop, is quite performant and mature, between a number of development environments.

Digital objects are stable and often persistent as the user moves about the space. Many of our textures, derived from high resolution diagnostic images, were hundreds of megabytes in size. This load did not have a substantial negative impact on object tracking. Still, we undertook a number of optimizations to streamline performance of the target tracking system:

- Tracker Image Enhancements: increased contrast and sharpness of the tracker image to improve tracking stability and reduced tracker image file size to ~2.4MB, aligning with Vuforia's recommendations for target images.
- Rendering Optimizations: switched from planes to quads to reduce the number of triangles, enabling faster rendering.
- Camera and Rendering Settings: Reduced near clipping plane distance to 0.01, the minimum allowed, for better close-up rendering. Set texture compression to ETC2 (GLES 3.0) in Android build options to reduce the overlay image sizes and facilitate faster rendering while still retaining quality.

The Vuforia/Unity development environment offers a central context from which to associate these varied media assets interactions, but for the sake of conceptual development of singular assets we rely on the Sketchfab online 3d viewer platform (Sketchfab, 2017). Sketchfab supports planar tracking across android and iOS devices, and employs features like subtractive masking of real world occlusion, which will show a person in the foreground of an XR scene over the digital object.

We had hoped to build an XR application using a device agnostic web-based system which would require only a camera and internet access. It would be very simple to add additional assets to hierarchical templates in an html page. Unfortunately, WebXR (2022) does not possess native support for image targets and required the use of additional plugins built upon open-source webGL tools like MindAR (2025) and AR.js (2025), we found that performance was very poor. Digital assets floated and flipped around above markers in the physical environment, even after all recommended measures were taken to simplify assets and reduce computational load. It was clear that webXR was not taking advantage of the modern sensor arrays on mobile devices, currently employed by Apple’s ARkit and Android AR (formerly known as ARcore).

5.2 User Experience

As one approaches a site included in the application and moves around, geotagged zones appear, upon opening one you will see a layer of information mapped in space, using your device as a lens you can walk around the piazza to explore the augmented reality installation while observing and being present in the place. The user can move into overlapping zones where different layers of information will appear which can be toggled and overlapped.

The user can capture images at any point in this experience to save them to their phone, to use for any purpose they choose such as sharing as a post on social media. These images are a critical component of co-creation, it is a token from an experience that the user created by overlaying the AR information with an integrated camera following the gesture of capriccio. However, this collaging of imagery is not a forgery meant to fool the viewer but a revelation of information that is not able to be seen with the naked eye.

The significance of this app is its exploration of an alternative way to reach the public in a way that is collaborative, engaging and considered. We desire to expand upon the portfolio of methods that are employable in sites of complex compounded heritage. This strategy also allows for more expansive narratives to be involved as it is dynamic not a static sign that that cannot be changed without being replaced, an app that can be updated, expanded and also incorporates input from the public / space for co-creation and sharing.

6. Discussion

It is our hope, that by presenting scientific data to the general public, along with the compelling research questions or curiosities, we will invite the public to engage with an unseen heritage. Just as how the dissemination of capriccio art engaged the public with a lens on cultural heritage that inspired curiosity it is our intention that the visual information we have made accessible to the public may result in a deeper understanding of the monuments that shape their own cultural heritage and, by extension, created a new sense of ownership and confidence in a past they have, until now, only imagined.

The current regime of public facing heritage communication in Florence consists of signage created and curated by experts intended to interpret the complex stratification of the built environment. Historical markers and signage are the current standard of heritage communication in public places. It is important to evaluate if this practice holds up to the needs and potentials to communicate to the public the complex and layered material tectonics that occur as a result of continuous inhabitation. The dynamics of this paradigm are ripe for interrogation, or furthermore a disruption. There is a wealth of revealing documentation that provides insights on heritage sites that are

developed and funded for the restoration of heritage sites around the world but rarely does this insightful work arrive to the public. With the proposed application, instead of beckoning the public to an information point, the public will have agency of their own pathway to explore the layers of the piazza on their own terms. This is the repositioning of the public not as an anonymous mass to be spoken to, but a collective of individuals who will be given the agency to chart their own courses as they engage with cultural heritage, thus assuming the role of the protagonist.

Breaking with the current formula of interest points punctuated by signage we propose a shift from a fixed point to a zone of engagement. Signs become zones of activity which are expansive and engage the subject matter of interest. A zone can have boundaries that are diffuse, and or overlap with neighboring zones which creates an exchanged dialogue with the potential for a narrative sequence which makes connections across multiple locations in multiple directions rather than following a numerated series or encountering signage which is not responsive or engaged with similar installations of the same type.

The typical signage present at heritage sites beckons a formulaic sequence of engagement, approach the sign, read some or all of the text, glance at possibly present images, look at the subject of the sign content, continue on. The zone of engagement makes no such implication of sequential behaviors, such that there is no one way to behave or expected to engage in a zone. There are a multitude of ways to engage with the cultural heritage that are non-formulaic and dependent on the interest of the user, the information is not presented to the user in a systematic and didactic way therefore the user is invited to and must make their own discoveries, forming authentic attachments and a sense of ownership over their learning. By repositioning the user as the protagonist, they will create a more profound sense of personal attachment and engagement with heritage, than a didactic could evoke. They will have not simply been told information, but will have led a path of discovery that is uniquely their own.

Acknowledgments

The authors would like to extend their thanks to Carol Tohsaku, Stefano Corazzini, Dr. Valentina Bonora, the Opera for Santa Maria Novella and to Arch. Francesco Sgambelluri.

References

AR.js development team (2025) AR.js Documentation v 3.4 https://ar-js-org.github.io/AR.js-Docs/

ArtGlass. “DUOMO TIME WALK. ESPERIENZA DI REALTÀ AUMENTATA ALLA SCOPERTA DEL DUOMO DI MILANO.” *ART-GLASS - Design your Augmented Reality* (blog), July 14, 2023. https://www.art-glass.it/2023/07/14/duomo-time-walk-esperienza-di-realta-aumentata-alla-scoperta-del-duomo-di-milano/.

ARKit. (n.d.). Apple Developer Documentation. Retrieved March 9, 2025, from https://developer.apple.com/documentation/arkit

Bent, G. (n.d.). *Florence As It Was*. Florence As It Was. Retrieved March 9, 2025, from https://florenceasitwas.wlu.edu/

Boboc, R. G., Băutu, E., Gîrbacia, F., Popovici, N., & Popovici, D.-M. (2022). Augmented Reality in Cultural Heritage: An Overview of the Last Decade of Applications. Applied Sciences, 12(19), 9859. https://doi.org/10.3390/app12199859

Campione, F. P. (2019). Capriccio. *International Lexicon of Aesthetics*, 8. https://doi.org/10.7413/18258630050

Dethier, J. (2014). The Double Nature of the Architectural Capriccio: From Pictorial Fiction to Urban Reality. In *The Architectural Capriccio*. Routledge.

Dieck, M Jung, TH., (2017) Value of augmented reality at cultural heritage sites: A stakeholder approach, Journal of Destination Marketing & Management, Volume 6, Issue 2, 2017, Pages 110-117, https://doi.org/10.1016/j.jdmm.2017.03.002.

Florence and its Province: The Archaeological Locations. (n.d.). [Map].

Giorgi, L. and Matracchi, P. (2015) “Florence: Knowledge and Accessibility of the Archaeological Heritage,”.

Google (2024) Explore new augmented reality features in Google Maps https://blog.google/products/maps/immersive-ar-content-google-maps-paris/

Gruppo TIM (2023) Santa Croce in Extended Reality https://www.gruppotim.it/it/innovazione/news-innovazione/Un-modo-nuovo-di-vivere-l-arte.html#lightbox

Hardie, C. (1965). The Origin and Plan of Roman Florence. *The Journal of Roman Studies*, *55*, 122–140. https://doi.org/10.2307/297435

Hess, M., Seracini, M., Petrovic, V., & Rissolo, D. Kuester, F. (2023). *Room of the Elements—Palazzo Vecchio , Italy* [Dataset]. OpenHeritage3D. https://doi.org/10.26301/7RQ9-X394

Lercari, N., Shiferaw, E., Forte, M., & Kopper, R. (2018). Immersive Visualization and Curation of Archaeological Heritage Data: Çatalhöyük and the Dig@IT App. Journal of Archaeological Method and Theory, 25(2), 368–392. https://doi.org/10.1007/s10816-017-9340-4

McAvoy, S. P; Seracini, M.; Bent, G. R; Pfaff, D.; Verdiani, G.; Mangano, D., et al. (2025). Data Report: Cappella Tornabuoni - Indagine preliminare termografica e geometrica . UC San Diego: Cultural Heritage Engineering Initiative (CHEI) at Calit2. Retrieved from https://escholarship.org/uc/item/7p96t403

McAvoy, S. P, Seracini, M., Bent, G. R, Pfaff, D., Rissolo, D., & Kuester, F. (2024). Data Report: Cappella Strozzi di Mantova - Indagine preliminare geometrica - ottobre 2024. UC San Diego: Cultural Heritage Engineering Initiative (CHEI) at Calit2. Retrieved from

https://escholarship.org/uc/item/5dn034xk

MindAR development team (2025) MindAR Documentation v1.1.0
https://hiukim.github.io/mind-ar-js-doc/

Nevola, F., Coles, T., & Mosconi, C. (2022). Hidden Florence revealed? Critical insights from the operation of an augmented reality app in a World Heritage City. Journal of Heritage Tourism, 17(4), 371–390. https://doi.org/10.1080/1743873X.2022.2036165

OurWorlds: Revolutionizing Learning Through Immersive Technology. (n.d.). Our Worlds. Retrieved March 9, 2025, from https://ourworlds.io/

Progetto Katatexilux. “Domus Aurea- Percorso Multimediale.” Rome, 2017. |
https://www.katatexilux.com/domus-aurea-1.

Salvini, M., & Faralli, S. (n.d.). *‘Archeologia invisibile’ a Firenze. Storia degli scavi e delle scoperte tra San Lorenzo, Santa Maria Novella e Fortezza da Basso*.

Sketchfab Development team (2017) Augmented Reality for Business (retrieved June 10 2025)
https://sketchfab.com/augmented-reality

Trachtenberg, M. (with Internet Archive). (2010). *Building-in-time: From Giotto to Alberti and modern oblivion*. New Haven [Conn.] : Yale University Press.
http://archive.org/details/buildingintimefr0000trac

Vanoni D., M. Seracini, M,. Kuester, F. "ARtifact: Tablet-Based Augmented Reality for Interactive Analysis of Cultural Artifacts," 2012 IEEE International Symposium on Multimedia, Irvine, CA, USA, 2012, pp. 44-49, doi: 10.1109/ISM.2012.17.

WebXR development team (2022) Repository for the WebXR Device API Specification., CRS-20220331
https://github.com/immersive-web/webxr