9 Immersive and extended reality (XR) technologies

This chapter focuses on extended reality technologies. Virtual models of historical and cultural sites offer credible recreations of absent or vanished environments, but the process of creating these models is labor-intensive, involving detailed construction and texturing of objects. This effort raises questions about authenticity, ethical concerns, and the potential for deception when a model's visual appeal conflicts with its accuracy. Additionally, the development of virtual experiences brings up issues regarding the perspectives and voices represented, and whether 3D simulacra can avoid problems of cultural objectification. High-resolution digital photography and imaging technologies like LiDAR are being used to capture and virtually restore at-risk cultural heritage sites without invasive excavation. These methods make monuments and artifacts accessible in unprecedented ways but require respect for the cultural property and intellectual provenance of the original artifacts. Scholars play a crucial role in ensuring that cultural experiences maintain critical considerations of argument and evidence, preventing them from being reduced to mere tourism.

9a XR formats and platforms: 3D, VR, AR, 360, LiDAR

Bonus content: a brief history of extended reality

The development of extended reality (XR) technologies, encompassing virtual reality (VR) and augmented reality (AR), was influenced by a variety of precursors and parallel innovations. The conceptual foundations of these immersive technologies can be traced back to the development of perspective largely credited to artists of the Renaissance period and to the early 20th-century invention of the stereoscope by Sir Charles Wheatstone, which provided a rudimentary form of three-dimensional visual perception.

Jim Boulton has identified a few events that have been crucial to the development of XR technology as we know it today. In the 1950s, filmmaker Morton Heilig envisioned an experience that could push the cinematic experience further by engaging more of the senses. By 1962, he had materialized this vision with the Sensorama, a patented device that integrates stereoscopic film, stereophonic sound, various piped smell, blown wind, and mechanical chair. This innovation marked the advent of what we now think of as VR technology, which quickly saw further developments with the expansion of digital computing hardware and software. For example, in 1966, the US Air Force pioneered their first flight simulator. This early implementation of AR technology eventually evolved into heads-up displays in military and commercial aviation. By 1968, Ivan Sutherland and Bob Sproull developed the first head-mounted VR system, a cumbersome device requiring ceiling suspension, colloquially known as the "Sword of Damocles." Once users were strapped into the device, the system featured rudimentary wireframe graphics representing basic rooms and objects. In 1979, the Aspen Movie Map was made at MIT, which was a virtual simulation of the town of Aspen. Think of it as an early version of Google Street View (which has been suspended in some parts of the world, like most areas of Germany). A lot of early development of these technologies, and frankly still to this day, is connected with the military industrial complex. Until fairly recently, most uses of immersive technology were restricted to training simulation and gaming. The mid-1980s witnessed Jaron Lanier founding VPL Research, commercializing VR goggles, and coining the term "virtual reality" (VR). Concurrently, Nintendo introduced the Power Glove, a VR haptic gaming interface that experienced limited commercial success. The proliferation of immersive technology into mainstream society can be largely attributed to the advent of the iPhone, which integrated applications with cameras, GPS, and touch interfaces. (Boulton 2014)

Bonus content: pioneering projects

Three-dimensional modeling takes spatial experience into a rendered representation that allows questions to be asked about the built environment that cannot be posed in other ways. Unlike maps, 3D images are often immersive, though they do not have to be.

For instance, one early virtual project, created in 1998, brought the expertise of a structural engineer, Kirk Martini, to bear on a historical inquiry into patterns of building reconstruction in Pompeii (Martini 1998). The project focused on a single building in the market of Pompeii that was damaged in an earthquake in 62 CE, a few years earlier than the famous eruption that buried much of the city in lava and ash from Vesuvius in 79 CE. Working with the archaeologist who was director of the larger Pompeii Forum Project, Martini analyzed patterns of damage and reconstruction using hundreds of photographs from which to extract the data for studying the chronology of the building's history of repair. Driving this research was a conviction that civic pride had pushed the reconstruction in the first century of Pompeii's history. But to prove that the building had been repaired required establishing the sequence of events preserved in the ruins—and extrapolating from this a hypothesis about the building in ancient times and between the earthquake and the eruption. Rubble patterns analyzed from an engineering standpoint combined with detailed study of the patches and repairs were keyed into a three-dimensional model of the building to assess whether these were ancient or more recent. Visual evidence, linked to a 3D model, allowed for exploration of this hypothesis.

Research using models not only contributes to knowledge of cultural heritage sites at a very granular level, exposing building techniques and construction technology, but also provides indications of the cultural value of these structures within their original society.

The Digital Karnak project, made more than a decade later, was created by a team of archaeologists and art historians. They reconstructed a major temple complex of ancient Egypt that existed for about two thousand years, from about 2055 BCE. During this period, the complex expanded into an elaborate site, including a massive main temple and dozens of buildings and structures around it. Each element is constructed from information in drawings from the excavated site, and every pylon, doorframe, wall, and other feature has to be created with scrupulous attention to historical accuracy. The elaborate models are shown mainly in video format, tracking the historical development of the site in animations (Figure 9.1).

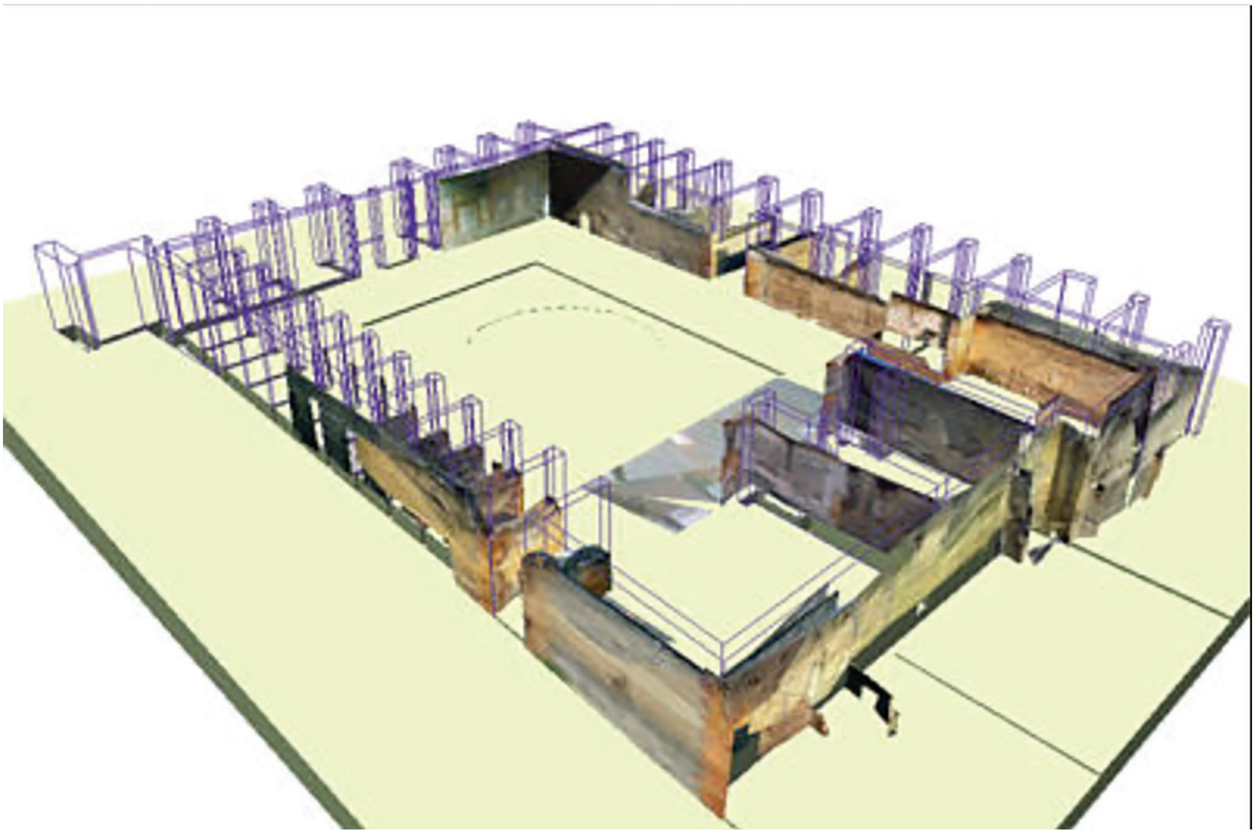

Figure 9.1 Kirk Martini, Pompeii project (Copyright 2010 Board of Visitors, University of Virginia All rights reserved.) http://www2.iath.virginia.edu/struct/pompeii/patterns/.

The project directors, Diane Favro and Willeke Wendrich, were careful to point out that no amount of research would recover the experience of the site in antiquity. But the model allowed hypotheses about the ways ritual processions moved through the site, and other issues, to be tested. Understanding of these activities changes when they can be situated in a virtual space.

Note that many of the renderings were made from a very high and exaggerated angle, one that would never have been occupied by a viewer in antiquity. The point of view is omniscient, and the quality of the rendering is schematic by contrast even to photographs of the remains on the site, with their distinct signs of age and texture, variation in color of stone, and the dazzling light and deep shadows of the Egyptian sun. The model remains a digital rendering, even in its Google Earth fly-through version. The access provided by this technology contrasts dramatically with the experience contemporary persons would have had of the same site. The ethics of representational strategies are complex.

Virtual Pompeii was made to test an engineering hypothesis and Karnak was used to study ritual processions and spaces, and to test the accuracy of literary texts and references. Many other virtual projects, each with their own agenda, could be cited (Uotila and Sartes 2016). Some are archaeological projects for which only ruins remain, so the reconstruction, speculative as it may be in many respects, is the only way to visualize these monuments. Unlike artists' two-dimensional renderings of the past, these models can be experienced in three dimensions and across time—and even be studied in a way that includes the remains (Figure 9.2).

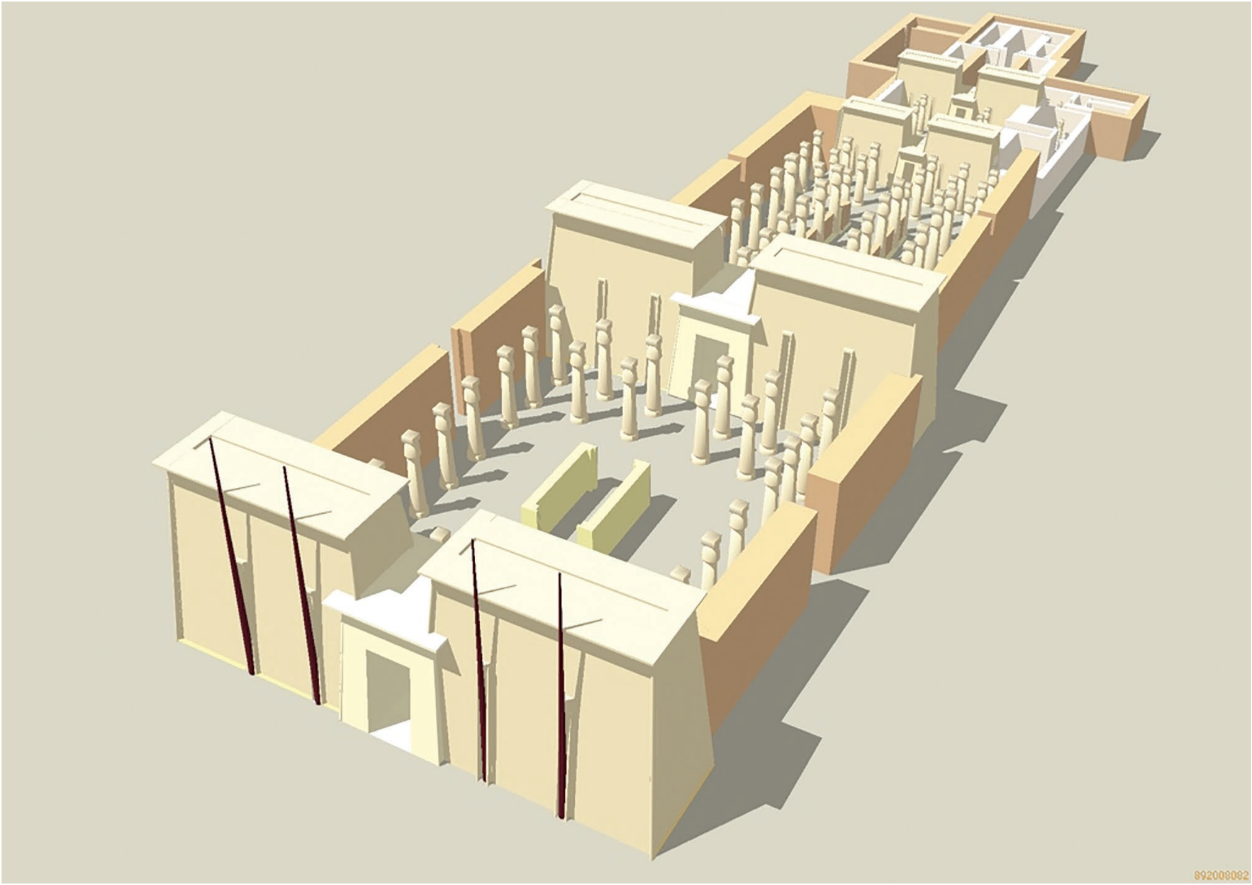

Figure 9.2 Digital Karnak Project: https://digitalkarnak.ucsc.edu (Image with permission of Willeke Wendrich and Elaine Sullivan. CC BY-NC 4.0. © Regents of the University of California, 2020.)

Classical scholar Christopher Johanson developed a virtual project to study the use of space in public spectacles, including funerals, in the Roman Forum in the Republic, comparing architectural and textual evidence (Favro and Johanson 2010). Johanson drew on concepts of refutability (could the argument be countered through evidence) and truth-testing (could the rendering be tested for accuracy to an original) within the virtual environment. This raises the question of whether "refutability" can be built into the visualization or virtual format. What does it mean to question an "argument" made in a model when the images are clearly reconstructions? Can another scholar access the evidence on which the model is made—not just the data underlying the virtual rendering, but the source materials on which that relies? The ethical issues around deception and truthfulness become more complex as the renderings become more realistic. Johanson added a useful distinction between "potential reality" and "ontological reality" of a monument. The first justifies the creation of virtual models as hypothetical objects, rather than representations of truth. The second argues for a pre-existing object against which the virtual model could or should be tested. As a humanist, Johansen was interested in interpretation, not just physical evidence.

An example of a virtual project with a different emphasis was created by Sheila Bonde to study life at the Abbey of Saint-Jean-des-Vignes in France (Bonde et al. 2017). Bonde's project focused on examining the site as a "physical expression of spiritual, social, and economic motives" in monasticism, not just a built structure. Bonde was interested in the interrelation of spatial form and social articulation. How did the monastic buildings structure gender relations, for example, limiting access for women to certain areas of the complex? What was the quality of life and the rhythm of work and seasons in a community in which "farms, mills, priories" and other components had to cooperate for their survival? Bonde also saw the web platform as a way to publish site drawings from the archaeological examination at the monastery—an undertaking that was too expensive to do in print.

By posting the primary evidence for her site, she made it possible for the texts governing daily life in the monastery to be available for a fuller understanding of tasks and rituals. The title, *Sensory Monastery*, signals the link between the study of architecture and the experiences of sound, touch, taste, sight, and visual senses—all as part of a spiritual community. In order to keep issues like the problems of "incomplete data" or "uncertainty" in the foreground, Bonde used non-realistic photographic methods in her renderings. Discussions of the representation of uncertainty—of how reliable the evidence is or the hypothesis about the structure extrapolated from it—play a part in virtual archaeology (Zuk and Carpendale 2007).

Mapping Gothic France, a pioneering work in digital architectural history, contained laser-drawn wireframes of all the cathedrals in the database. These can be compared feature by architectural feature—nave height, aisle width, floor plans, and sections (Murray n.d.). Without a way to digitize the physical structures and make them into data models that can be manipulated, this work would be impossible. Is there a risk that this approach reduces complex cultural artifacts to positivist renderings of their physical properties? The argument can be made that the research allowed new questions to be asked about style, influence, and symbolic qualities. A project carried on at Duke University used crowdsourcing to generate enough images for a high-resolution photogrammetric model of its neo-Gothic chapel. The contrast between the rendering of Duke's chapel in cloud points and that of the Gothic France project stresses the difference between a special effects rendering and a systematic project conceived from a scholarly perspective that made use of 3D models for analytic purposes.

Bonus content: a note on VSim

Three-dimensional models, once built, need an environment in which to be used. VSim is a framework built specifically to meet the needs of scholars. Developed by Lisa Snyder, director of the *Chicago Columbian Exposition* project, it is a presentation environment (Viele 2015). VSim allows production of narratives to frame that experience. In addition, it supports embedding source documents within the model itself. Since many historical models built in three dimensions draw on primary sources for their information, the capacity to add annotation, metadata, and commentary into the models allows a user to see what has been extrapolated, what has been copied, and where decisions about the model do and do not rely on historical documentation.

The contrast between the rendered model, with its highly studied and carefully constructed forms and surfaces, and the primary sources in the form of postcards, photographs, and memorabilia, makes for a useful critical dialogue between evidence and representation. Questions of what we see and how, which features of visual experience become significant over time, and the distance from the perceptual capacity of individuals in different periods or locations, becomes vivid as a result. The historical context of viewing, experiencing a building or object, cannot be recovered—but at least, it can be noted as an absent feature of the dynamics of modeling. Presentation of evidence legitimates the scholar's work so it can be assessed by others. Argument and evidence are not the same and keeping both in view in a virtual environment is an important scholarly principle (Figure 9.3).

Figure 9.3 VSim showing embedded resources for the 3-D model of the Chicago Columbian Exhibition. The image is a screengrab from a real-time simulation model of the Street of Cairo installation on the midway at the World's Columbian Exposition held in Chicago in 1893. The model was begun under the auspices of the Urban Simulation Team at UCLA and is now supported by UCLA's Office of Advanced Research Computing and Institute of Digital Research and Education.

Source: (Image courtesy of Lisa M. Snyder. © Regents of the University of California, 2025.)

Bonus content: critical issues in 3D

There are some common characteristics at the core of most XR scholarship to keep in mind. When assessing a project, consider if these elements are defining aspects or goals for the use of XR in the project:

- Object-oriented design
- Layering realities or intersecting the physical and virtual

- Bridging differences in time and space, often by occupying virtual space (together)
- Suspending disbelief
- Experiencing (dis)embodiment and (dis)orientation
- Engaging perception and reception
- Exploring intersections of time, memory, and history

Exercise 9.1: Conceptualizing a project

Using this lesson from Programming Historian (https://programminghistorian.org/en/lessons/creating-mobile-augmented-reality-experiences-in-unity) as a guide, conceptualize a project in AR.

Exercise 9.2: Tinkercad tutorial

Tinkercad (https://www.tinkercad.com/) is a great program for learning the basics of 3D modeling. Learn some 3D modeling terminology and practice some 3D modeling skills by completing a Tinkercad tutorial (https://docs.google.com/presentation/d/1Bzm2JUA5Tu6rJlw-_JAVkD_CazEwJ7o-WY6c1eB96Vk/edit?usp=sharing).

Exercise 9.3: Dunhuang caves

What features of the caves are readily understood from this online imaging? What are not?

- Digital DunHuang (http://www.e-dunhuang.com/)
- About the International Dunhuang Programme (http://idp.bl.uk/pages/technical_infra.a4d)
- Hu, Xiao. (2018). Usability Evaluation of E-Dunhuang Cultural Heritage Digital Library. Data and Information Management. 2. 10.2478/dim-2018-0008 (http://www.researchgate.net/publication/326804961_Usability_Evaluation_of_E-Dunhuang_Cultural_Heritage_Digital_Library).

How-to example

Online imaging of caves, such as that provided by platforms like E-Dunhuang (http://www.e-dunhuang.com/), allows users to readily understand features like architectural details, wall paintings, inscriptions, and overall spatial layouts. However, limitations include the inability to fully capture the ambient atmosphere, tactile sensations, and the true scale of certain features. Additionally, the quality of online images can be affected by factors like lighting conditions, resolution, and the technology used for capturing the images.

Exercise 9.4: Sketchfab

Compare the commercial part of Sketchfab (https://sketchfab.com/) with the section curated by a University of North Carolina Research Lab (https://sketchfab.com/rla-archaeology). Be sure to go back to the lab's website (https://archaeology.sites.unc.edu/home/rla/collections/#3D) and look at their cataloging standards, documentation, and record-keeping. What differences do you notice in terms of description, licensing, and quality control?

How-to example

The commercial part of Sketchfab provides general descriptions and licensing information, while the RLA Archaeology section offers detailed archaeological descriptions and historical context. In addition, Sketchfab's licenses are focused on commercial and editorial use, whereas the RLA Archaeology artifacts are typically not for sale and are used for educational and research purposes. Finally, the RLA Archaeology section has rigorous cataloging and documentation standards to ensure the accuracy and integrity of the artifacts, whereas Sketchfab relies on user-generated content with varying levels of detail and accuracy.

Recommended readings

Anderson, Steve F. 2017. *Technologies of Vision: The War between Data and Images*. Cambridge: The MIT Press.

Clark, Jasmine L. 2021. "Recommendations for Accessible Pedagogy with Immersive Technology." *#DLFteach Publications*. Retrieved from https://dlfteach.pubpub.org/pub/vol2-clark-recommendations-for-accessible-pedagogy-with-immersive-technology.

Nieves, Angel David, Kim Gallon, David J. Kim, Scott Nesbit, Bryan Carter, and Jessica Johnson. 2017. "Black Spatial Humanities." *ADHO Abstracts*. https://dh2017.adho.org/abstracts/285/285.pdf.

Papdopoulos, Costas, and Susan Schreibman. 2019. "Towards 3D Scholarly Editions: The Battle of Mount Street Bridge." *Digital Humanities Quarterly* 13 (1). www.digitalhumanities.org/dhq/vol/13/1/000415/000415.html.

9b Immersive technologies: workflow and analysis

Bonus content: manual modeling

Building a model from scratch requires a modeler to focus on the form of the object, including the details and proportions that provide enhanced realism. For bibliography or source-based modeling, where models are built based on references like documents, photographs, or other information regarding real-world objects and places, this may mean making educated guesses or multiple models to represent different possibilities when there is a lack of sourced-based information. **[See CW: A note on VSim]** Even when creative modeling (i.e., modeling for artistic or creative purposes), critically thinking through the organization of the model's various components can help with its adaptability and reuse. The surface quality and level of detail will affect the model's polygon or voxel count, which in turn will dictate how the model performs. Low-poly or low-voxel models are lighter files and render more quickly but provide less detail. As you increase the polygon or voxel count, the more detailed geometry will result in a smoother and more realistic appearance, but will require more computing power to render.

Bonus content: reality-capture methods

Scanning can be done using a variety of light sources, including structured light scanning, laser scanning, and photogrammetry for objects in a laboratory (LIDAR and other scanning operations are used for large-scale projects). Photogrammetry uses two-dimensional images as data to create a mesh output. Typically this requires precise camera location in addition to the image data; however, structure-from-motion (SfM) method does not need camera position to create a 3D model from overlapping images. These 3D models are enhanced by the color information that can be mapped to the surfaces of the object. The scanners work by projecting light and then capturing the reflected data. Laser scanning may use a time-of-flight method, a phase method, or a triangulation method to create point clouds or meshes that can again be textured by color information captured at the points or vertices. A 2D image can also be used to texture map to such meshes. Structured light models a form by measuring distortions in projected light in a grid or patterned form, and produces a mesh output that can be enhanced by applying vertex color or 2D texture image from an image (Moore et al. 2022). Because of this reflective technology, the surface properties of the object have to be taken into account. For instance, in some cases, as in scanning polished glass, a film of some kind will need to be applied and special coatings that evaporate after use have been invented for this purpose. Rising in popularity are NeRFs and Gaussian splatting techniques. NeRFs (short for neural radiance fields) can create a continuous volumetric scene through the use of deep learning with fewer images than typical photogrammetry. While less precise than photogrammetry, NeRFs are ideal for visualizing entire rooms or landscapes. Gaussian splatting also visualizes volumetric data but can render much more quickly thanks to the rasterization of the data, breaking them down into sections or "splats," which are blended together. In terms of modeling techniques that are commonly used in the medical field, computed tomography or CT scans create a model by combining many cross-sectional X-ray images or "slices" to build up a model and 3D magnetic resonance imaging use magnetic fields and radio waves to produce image slices in a similar fashion, which allows for non-invasive visualizing inside an object or living being.

Bonus content: minimum files for access and maximum files for preservation

The following was generated with Lisa M. Snyder as part of work for Community Standards for 3D Preservation (CS3DP) group (https://dev.cs3dp.org/).

In general, minimum files for access for XR materials (presuming intent to reuse as 3D geometry and interaction as content creator intended) should include:

- Final version of the 3D model(s) in preservation file format and native file format
- Final texture maps, material files, palettes, and shadow maps (file structure may be critical)
- Stable version(s) of the software required to view and interact with said files (e.g., Creator, 3Ds, Maya, SketchUp, Google Earth)
- Metadata and paradata that describes the project(s) and decisions made during the creation of the model
- If a real-time environment, the final aggregated binary files and the software necessary to "fly" the model
- Camera locations, and if a Google Earth model, any GIS-related files and spreadsheets

But if we want to treat XR art and scholarship like we treat other work in the archive, there are so many more related materials we would want for preservation, such as correspondence related to the project, publicity and marketing materials, data describing project decisions and changes, and various iterations of the work in progress. Here is how the list above might be updated for prioritizing preservation:

- 3D computer models in different formats (e.g., obj, dae, native file formats)
- Versioned copies of the 3D model files

- Textures maps, materials files, palettes, and shadow maps that go with the different model versions (file structure may be critical)
- Stable version of the software required to view and interact with said files (e.g., Creator, 3Ds, Maya, SketchUp/Google Earth)
- Videos generated from the computer model; static images generated from the computer model (screenshots and renderings)
- Correspondence related to the project; and publicity/marketing related to the project
- Metadata and paradata that describe the projects and decisions made during the creation of the model; research files and documents in various formats (scans, pdfs, bibliographic information, etc.
- If a real-time environment, various iterations of the aggregated binary files and the software necessary to "fly" the model
- If a Google Earth model, GIS-related files and spreadsheets if time periods are included; if used for creation of other materials (e.g., teaching resources or a film production), work files related to the final output and copies of that final output; analog documents and artifacts relating to the 3D model

Bonus content: virtual restoration and non-invasive archaeology

The restoration of art historical objects often generates controversy. The physical alteration of remains of statues or monuments relies on interpretation and speculation. The act of making changes to the remains of a once intact object—or even cleaning an artifact that has accumulated so much discoloration or dirt from wear—can involve changes that do damage of their own. Altering any historical work of art involves risks. So, the possibilities of doing this virtually, even allowing for multiple restorations that reflect different opinions, offer one solution to this dilemma. **[Bonus exercise: ALiVE.]**

Bernard Frischer's digital sculpture project offers one case study in this area. Focused on a statue of the Roman Emperor Caligula, the project committed to scanning, digital restoration, and multiple hypotheses on the original coloration of a single statue (Frischer n.d.). The research team wanted to be able to indicate degrees of uncertainty about their historical hypotheses. Since most classical marble sculptures were originally polychromed, the recovery of small bits of pigment from the existing object can be used as a guide in digital restoration. Such remains are not always sufficient. Base coats and preparatory layers might be what remains, rather than final surface tones. Extrapolating from existing evidence involves informed guesswork. One challenge is to provide visual cues to indicate degrees of uncertainty about the features of the restoration. This can be difficult in the technology of photogrammetry since its photo-realistic renderings offer a sense of replete-ness and finish. The solution proposed by the Caligula team was to present variant alternatives of the restoration in order to demonstrate their hypothetical character. The argument from within a conservation community involves a distinction between an intervention that conserves a physical artifact and one that imposes an artistic judgment. Digital restoration allows the physical object to be stabilized independently and theories of its original appearance to be produced anew into perpetuity (Figure 9.4).

Figure 9.4 Two views of Caligula, created by Matthew Brennan, Virtual World Heritage Laboratory.

Source: (Courtesy of Bernard Frischer. Copyright 2010 Board of Visitors, University of Virginia. All rights reserved.) www.digitalsculpture.org/papers/frischer/frischer_paper.html.

Bonus content: analysis and study of photogrammetry and 3D capture

For purposes of research, photogrammetry can be used to reconstruct a lost or destroyed building or monument from historical records. One such project worked from a repository of historic photographs of the Kronentor gate in Dresden (Maiwald et al. 2017). The goal of the project was to see if a 3D model could be constructed from the information in historical photographs. Using a technique called SfM, the researchers put together a model by using images taken from different viewpoints. These photographs were themselves archival objects, not images produced for this purpose. The gate was destroyed in the 1945 bombings, and though later reconstructed, the goal of the research was to recover the earlier structure. The account of the project documents the process, use of the software Agisoft PhotoScan, and the derivation of the point clouds (data points aggregated to create an image) from the photographs—on which the specific features of the model are built.

In archaeological research, the labor-intensive task of matching fragments of pottery with possible original shapes benefits from digital models and renderings (Zvietcovich et al. 2016). The idea of automatic matching involves extrapolation of information from a fragment to compare it with an "implicit" form (Maiza and Gaildrat n.d.). Matching a "shape model" and a fragment and building a hypothetical object of which it is a part involves computational processing of thickness, angles, and every detail of the form to try to guess what the original larger object looked like and where in that overall shape the fragment belonged. This reverse engineering of a form based on assessments of "distance" between the fragment and its place in the original object is rendered using the same kind of meshwork as that in VR techniques. The hybrid of analytic photogrammetry and virtual modeling can produce remarkable results, even if they must be treated with requisite caution with regard to authenticity.

Digital imaging techniques promote methods of analysis through formal contrast and comparison, as well as in their application to individual objects. CyArk, a nonprofit founded by civil engineer Ben Kacyra in 2003, has been partnering with governments and communities across the world to 3D laser scan significant cultural heritage sites. These immersive digital twins support a wide range of preservation, conservation, and restoration efforts and also foster research and education with low impact to the site. In addition, their newly developed web and mobile platform Tapestry layers interactive, media-rich, multivocal, and place-centric narratives over these immersive scans to provide additional cultural, social, and historical context.

However, the close association of XR technology with the entertainment and gaming industries can pose a challenge or even a liability to using XR methods for research and scholarly outputs (Theodoropoulos and Antoniou 2022). As manipulation and hybridization become familiar, do they emphasize superficial approaches to the study of cultural artifacts and sites, losing sight of the symbolic dimensions? When the history of human production becomes an inventory of objects or places to be played with, will they lose their connection to the fabric of social relations? The artifacts and sites may become autonomous objects, more likely to be appreciated for their formal qualities than for the more complex aspects of their cultural role and identity. **[See Exercise 9.6: Cultural artifacts.]**

Exercise 9.5: Polycam tutorial

Practice some photogrammetry familiarizing yourself with Polycam (https://poly.cam/) and then complete this Polycam tutorial (https://docs.google.com/presentation/d/11EPGcB3bT5RKkN5D8E-zC4-e3jU0f0P9K9CgQFQog7k/edit?usp=sharing).

Exercise 9.6: Cultural artifacts

Explore the possibilities of the Smithsonian 3D Labs website (https://3d.si.edu/labs) and consider how the effects created do and do not increase understanding of the artifacts in the collections. Can you think of alternatives to these approaches that might be more instructive? Compare with Google Arts and Culture (https://artsandculture.google.com/) and think about the line between entertainment and scholarship.

How-to example

The Smithsonian's 3D Digitization Labs offer interactive tools like Voyager Story, Voyager Paint, and Voyager CT scans, which enhance understanding by allowing users to explore, color, and examine artifacts in detail. However, these features may not fully convey the tactile and historical context of the artifacts. In contrast, Google Arts & Culture provides a broader range of cultural content from over 2,000 institutions worldwide, including high-resolution images and virtual tours, which can offer a more comprehensive educational experience. While both platforms blend entertainment and scholarship, Google Arts & Culture's extensive partnerships and user-friendly interface may provide a more instructive approach for engaging with cultural heritage.

Exercise 9.7: Supporting long-term access

Review all the tables in APPENDIX 6A found on page 281 of *3D Data Creation to Curation: Community Standards for 3D Data Preservation* (https://bit.ly/ACRL3Ddata). Then consider what types of work you would need to save to preserve one of the experiences on this Virtual Reality Apps Library list (https://sc.edu/about/offices_and_divisions/cte/teaching_resources/virtual_environments/virtual_reality_apps/index.php).

How-to example

For a VR film project shot with a 360 camera, such as Traveling While Black (https://digitaldozen.io/projects/traveling-while-black/), a list of maximum files for preservation might include:

- Raw 360 video files: The original, unedited footage captured by the 360 camera.
- Stitched video files: The stitched versions of the raw footage, combining the multiple camera feeds into a single 360-degree video.
- High-resolution master files: The highest quality versions of the edited film, typically in formats like ProRes or DNxHR.
- Compressed/delivery formats: Versions of the film in formats suitable for online streaming or distribution, such as H.264 or H.265.
- Metadata files: Information about the video files, including camera settings, shooting locations, and any relevant technical details.
- Project files: Files from editing software (e.g., Adobe Premiere, Final Cut Pro) that include the timeline, edits, effects, and transitions applied to the video.
- Sound files: Separate audio recordings, sound effects, and music tracks used in the film.
- Documentation: Detailed records of the production process, including shot lists, scripts, and production notes.
- 360-Specific metadata: Information specific to 360 videos, such as spherical metadata and viewing parameters.
- Interactive elements: If the film includes interactive elements, such as hotspots or annotations, save the files related to these features.
- Subtitles and captions: Text files for any subtitles or captions included in the film.

Preserving these files ensures that the 360 film can be accurately recreated, edited, and experienced in the future.

Exercise 9.8: Open heritage project

Look through this article (https://www.evolving-science.com/information-communication/virtual-reality-00732) and the Open Heritage Project (https://artsandculture.google.com/project/cyark), CyArk (California), and consider the implications of virtual cultural tourism.

How-to example

The Open Heritage Project, developed by CyArk, seeks to make 3D cultural heritage data accessible for education, research, and non-commercial purposes. This project preserves and shares detailed digital records of cultural sites with a global audience. Facilitating virtual cultural tourism allows people to explore heritage sites from anywhere, promoting accessibility and cultural understanding, while simultaneously lessening carbon emissions by avoiding likely air travel. However, it's important to consider cultural sensitivity, ensuring digitization respects community values, maintaining the quality and longevity of digital records, and preventing the misuse of cultural heritage data. While virtual cultural tourism provides exciting opportunities for education and engagement, careful consideration is needed to benefit both the heritage sites and their communities.

Bonus exercise: ALiVE

Imagine possibilities for these immersive installation options (http://www.vi-mm.eu/2017/12/20/alive-project-city-university-of-hong-kong/) to be useful in a research project

How-to example

By employing projection mapping on domed or rounded surfaces, researchers can closely examine the construction of historical domes. This technique overcomes challenges related to location, height, and scale, which typically make comparisons difficult. Immersive projection enables researchers to safely and efficiently switch between different environments, allowing them to contrast various construction methods and assess restoration needs without compromising their safety or disrupting the physical space.

Recommended readings

Ioannides, Marinos, and Petros Patias, eds. 2023. 3D *Research Challenges in Cultural Heritage III: Complexity and Quality in Digitisation*. Cham: Springer International Publishing, ISBN 9783031355929. https://library.oapen.org/handle/20.500.12657/75405

Diniță, Alin, Adrian Neacșa, Alexandra Ileana Portoacă, Maria Tănase, Costin Nicolae Ilinca, and Ibrahim Naim Ramadan. 2023. "Additive Manufacturing Post-Processing Treatments, a Review with Emphasis on Mechanical Characteristics. *Materials (Basel)* 16: 4610. https://doi.org/10.3390/ma16134610.

Kafle, Abishek, Eric Luis, Raman Silwal, Houwen Matthew Pan, Pratisthit Lal Shrestha, Anil Kumar Bastola. 2021. "3D/4D Printing of Polymers: Fused Deposition Modelling (FDM), Selective Laser Sintering (SLS), and Stereolithography (SLA)." *Polymers (Basel)* 13: 3101. https://doi.org/10.3390/polym13183101.

Kantaros, Antreas, Theodore Ganetsos, Florian Ion Tiberiu Petrescu. 2023. "Three-Dimensional Printing and 3D Scanning: Emerging Technologies Exhibiting High Potential in the Field of Cultural Heritage." *Applied Sciences (Basel)* 13: 4777. https://doi.org/10.3390/app13084777.

Kantaros, Antreas, Maria I. Papageorgiou, Konstantinos Brachos, Theodore Ganetsos, Stella Mouzakiotou, Evangelos Soulis. 2024. "The Use of 3D Scanning and 3D Color Printing Technologies for the Study and Documentation of Late Bronze Age Pottery from East-Central Greece." *Journal of Mechatronics and Robotics* 8: 11–9. https://doi.org/10.3844/jmrsp.2024.11.19.

Bibliography

Albrezzi, Francesca. 2019. "Virtual Actualities: Technology, Museums, and Immersion." PhD diss., University of California, Los Angeles. https://escholarship.org/uc/item/5tc2q2dt.

Al Sayyad, Nezar. 1998. "Virtual Cairo: An Urban Historian's View of Computer Simulation." *Leonardo* 32 (2): 93–100. www.jstor.org/stable/1576690?seq=1#metadata_info_tab_contents.

Bakker, Geeske, et al. 2003. "Truth and Credibility." *The Journal of Visualization and Computer Animation* 14 (3): 159–67. https://onlinelibrary.wiley.com/doi/abs/10.1002/vis.314.

Bonde, Sheila, Alexis Coir, and Clark Maines. 2017. "Construction-Deconstruction- Reconstruction." *Speculum* 92 (S1). www.journals.uchicago.edu/doi/full/10.1086/694169.

Boulton, Jim. 2014. *100 Ideas That Changed the Web*. [Enhanced Credo edition]. London and Boston, MA: Laurence King Publishing, Credo Reference.

Community Standards for 3D Data Preservation (Initiative). 2022. *3D Data Creation to Curation: Community Standards for 3D Data Preservation*, edited by Jennifer Moore, Adam Rountrey, and Hannah Scates Kettler. Chicago, IL: Association of College & Research Libraries. https://bit.ly/ACRL3Ddata.

Cumming, Vivien. 2017. "We May Have Cracked the Mystery of Stonehenge." *BBC*. www.bbc.com/travel/story/20170713-why-stonehenge-was-built.

Favro, Diane, and Christopher Johanson. 2010. "Death in Motion: Funeral Processions in the Roman Forum." *Journal of the Society of Architectural Historians* 69 (1): 12–37. www.jstor.org/stable/pdf/10.1525/jsah.2010.69.1.12.pdf.

Frischer, Bernard. n.d. "Digital Sculpture Project." *Caligula*. www.digitalsculpture.org/papers/frischer/frischer_paper.html.

Gallon, Kim. 2016. "Making a Case for Black Digital Humanities." In *Debates in the Digital Humanities*, edited by Matthew Gold and Lauren Klein. Minneapolis: University of Minnesota Press.

Google, Arts and Culture Exhibits. n.d. Chichén Itzá, Mexico https://artsandculture.google.com/exhibit/OgLSnnqWE9B_IQ.

Google, Arts and Culture Exhibits. n.d. Chavín de Huántar, Peru https://artsandculture.google.com/exhibit/VwLyaBwv7bFPKA.

Janzekovic, Petja. 2017. "Alive Project: City University of Hong Kong." *Virtual Multimodal Museum*. www.vi-mm.eu/2017/12/20/alive-project-city-university-of-hong-kong/.

Johnston, Jessica. 2015. "An Archive for Virtual Harlem." https://scalar.usc.edu/works/harlem-renaissance/index.

Jones, Steven E. 2015. "Ch. 6 New Media and Modeling: Games and the Digital Humanities." In *A New Companion to Digital Humanities*, edited by Susan Schreibman, Ray Siemens, and John Unsworth. Wiley and Sons. https://doi.org/10.1002/9781118680605.ch6.

Lischer-Katz, Zack, Rashida Braggs, and Bryan Carter. 2024. "Investigating Volumetric Video Creation and uration for the digital humanities: a white paper describing findings from the project: Preserving BIPOC Expatriates' Memories During Wartime and Beyond." [White paper]. https://doi.org/10.2458/10150.674673.

Liu, Melinda. 2012. "Virtual Tourism: China's Dunhuang Buddhist Caves Go Digital." *Newsweek*. www.newsweek.com/virtual-tourism-chinas-dunhuang-buddhist-caves-go-digital-63615.

Maiwald, F., T. Vietze, D. Schneider, F. Henze, S. Münster, and F. Niebling. 2017. "Photogrammetric Analysis of Historical Image Repositories." https://d-nb.info/1143876547/34.

Maiza, Chaouki, and Véronique Gaildrat. n.d. "Automatic Classification of Archaeological Potsherds." https://www.researchgate.net/publication/228355481_Automatic_classification_of_archaeological_potsherds.

Martini, Kirk. 1998. "Patterns of Reconstruction at Pompeii." *University of Virginia, IATH*. https://www2.iath.virginia.edu/struct/pompeii/patterns/.

Meier, Allison. 2015. "Virtually Visiting the Harlem Renaissance." *Hyperallergic*. https://hyperallergic.com/229303/virtually-visiting-the-harlem-renaissance/.

Mercer, Kobena. 1990. "Black Art and the Burden of Representation." *Third Text* 4 (10): 61–78. www.tandfonline.com/doi/abs/10.1080/09528829008576253?journalCode=ctte20.

Milgram, Paul, and Kishino, Fumio. 1994. "A Taxonomy of Mixed Reality Visual Displays." *IEICE Transcations on Information Systems* e77-D (12): 1321–29.

Mulvey, Laura. 1975. “Visual Pleasure and Narrative Cinema.” In *Visual and Other Pleasures*. New York: Palgrave Macmillan. https://doi.org/10.1007/978-1-349-19798-9_3.
Murray, Stephen. n.d. “Mapping Gothic France.” https://mcid.mcah.columbia.edu/mapping-gothic.
Soo, Daniel. 2016. “A New Age of VR Involving All Five Senses.” *ISPR Presence*. https://ispr.info/2016/08/02/a-new-age-of-vr-involving-all-five-senses/.
Theodoropoulos, Anastasios, and Angeliki Antoniou. 2022. “VR Games in Cultural Heritage: A Systematic Review of the Emerging Fields of Virtual Reality and Culture Games” *Applied Sciences* 12 (17): 8476. https://doi.org/10.3390/app12178476.
UNESCO. “Magao Caves.” n.d. https://whc.unesco.org/en/list/440/.
Uotila, Kari, and Mina Sartes. 2016. “Medieval Turku, Finland—the Lost City.” *Virtual Worlds in Archaeology Initiative*. http://www.learningsites.com/VWinAI/VWAI_Turku-home.php.
Viele, Nico. 2015. “World’s Columbia Exposition of 1893 Comes Alive on Computer Screens.” https://newsroom.ucla.edu/stories/worlds-columbian-exposition-of-1893-comes-alive-on-computer-screens.
Wendell, Augustus, Burcak Ozludil Altin, and Ulysee Thompson. 2016. “Prototyping a Temporospatial Simulation Framework.” *Complexity & Simplicity: Proceedings of ECAADE* 2: 485–91.
Zuk, Torre, and Sheelagh Carpendale. 2007. “Visualization of Uncertainty and Reasoning.” https://link.springer.com/chapter/10.1007/978-3-540-73214-3_15.
Zvietcovich, Fernando, et al. 2016. “A Novel Method for Estimating the Complete 3D Shape of Pottery with Axial Symmetry from Single Potsherds Based on Principal Component Analysis.” *Digital Applications in Archaeology and Cultural Heritage* 3 (2): 42–54. www.sciencedirect.com/science/article/pii/S2212054816300078.

Resources

- Smithsonian 3D (https://3d.si.edu/)
- Voyager Story Standalone (https://3d.si.edu/voyager-story-standalone)
- The Dataverse Project (https://dataverse.org/)
- Cahokia AR Tour (https://cahokiamounds.org/augmented-reality-project/)
- CyArk (https://cyark.org/)
- Kompakkt (https://kompakkt.de/home)
- MorphoSource (https://www.morphosource.org/)
- Potree (https://potree.github.io/)
- Sketchfab (https://sketchfab.com/)
- Tapestry by CyArk (https://tapestry.cyark.org/)
- Thingiverse (https://www.thingiverse.com/)
- Turbosquid (https://www.turbosquid.com/)
- UMORF (https://umorf.ummp.lsa.umich.edu/wp/)
- Universal Viewer (https://universalviewer.io/)
- The Metamuseum Project (https://vwhl.luddy.indiana.edu/projects/Metamuseum.html)
- W3C XR Accessibility User Requirements (https://www.w3.org/TR/xaur/)
- 3DHOP (https://3dhop.net/index.php)