Merging archaeological site recreation and museum exhibition

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Abstract. Archaeological projects require a great amount of work in the representation and storage of digital data about the excavation of the archaeological site, the information about the encountered findings, and the analyses carried out by the laboratories and the consequent interpretations of the facts. However, though archaeological databases are of primary importance for retracing the interpretation processes and identifying the supporting elements, they often remain a pure archive, with no more accesses after the excavation activities; often, disciplinary experts work in isolation, and usually relying on scientific literature that rarely includes a friendly access to the datasets. A well-known presentation setting in archaeology is to exhibit results through virtual reality. Virtual reality yields the recreation of the remote site in a geospatial layout as well as the reproduction the diachronic phases of the excavation and the encounter of findings.
This paper presents BeA-ViR, an application for virtual archaeology that is devoted to traversing boundaries and borders on multi-cultural dimensions (Japan-Europe), multi-targeted audiences (general audiences and multi-disciplinary scholars), and multiple platforms (desktop, CAVE, and web). It relies on a comprehensive database that merges archaeological and archaeometric knowledge about the site and the findings.

Keywords: Archaeology · Virtual reality · Traversing borders

1 Introduction

Archaeological projects produce such a large amount of digital information that some researcher stated that "excavation is digitization" [27]. Data have been increasing with the advent of archaeometry, which includes the activities of measurement and interpretation carried out by hard scientists, and imaging, where photogrammetry and laser scanning implement the documentation of the archaeological sites before, during, and after the destructive processes of the excavation (see, e.g., [24],[36]). Also, the *digital twins* that result from the digitization of the encountered artifacts contribute to morphological research as well as to conservation, restoration, and communication processes [2]. All these data are collected, curated and recorded in suitable databases [16][13]. These datasets are then available online through public repositories, such as the Digital Archaeological Record[1] and the Archaeology Data Service[2], for quantitative analyses that yield novel interpretations (see, e.g., [29]) and for dissemination purposes in exhibitions (see, e.g., [3]).

For both research and dissemination, a relevant role is played by virtual reality, that exploits the abundance of 3D models elaborated from the photographic documentation of excavation and artifacts. *Virtual* or *digital archaeology*, a collective term for the use of digital technology to investigate and communicate about the past, uses interactive multimedia, immersive environments, and three-dimensional modeling to recreate and visualize sites and artifacts [26] (see [23] for a recent review). VR applications for archaeology can provide explorations of the sites, by providing access to the metadata concerning sizes, distances, materials, or chronology, and representing the different excavation campaigns in different sub-environments distributed along some diachronic scale [16]. In other, more spectacular applications, famous sites are exposed to the general public, to enjoy reconstructions of buildings and life in the ancient site, providing a suitable storytelling that illustrates the available up to date interpretations about the community who have been historically living the site (e.g., [20]). In general, there has been a vast debate on what is storytelling for archaeology, sometimes oscillating between technical scientific writing and creative historical narratives (i.e., fictional narratives based on archaeological record and anthropological theory). The goal is to identify a multiplicity of writing formulas, ranging from academic conformity with the past to "better ways to connect our [i.e., archaeologists'] interests with the public interest so we might have empathy for people in the past as well" [33, p. 171].

Archaeological projects can last decades, while excavation campaigns follow one another, accumulating digital data and metadata, long before an interpretative model recognized and shared by the scientific community can be elaborated. The database is updated while the excavation activities and the laboratory analyses go on and it also happens that exhibitions are organized to engage the interested human communities with the project. These communities are the depository of the values that motivate the conservation of the archaeological site [34]. In these cases, an updatable virtual environment is a viable solution for informing the communities and keeping alive the digital materials, which suffer obsolescence and inaccessibility [14]. The virtual environment must merge the conventions for the exhibition of the archaeological site (reconstruction of known parts, hypotheses to be reported, and artist inventions to be marked) with the conventions of the museums for the exhibition of artifacts, with information extracted from the database and exhibited together with items from related sites. Both conventions assume an interactive narrative approach for organizing materials and engage public in the exploration of archaeological matters.

[1] `http://www.tdar.org/`, visited on 15 September 2023.
[2] `http://archaeologydataservice.ac.uk/`, visited on 15 September 2023.

This paper presents a VR application, called BeA-ViR, that merges the reconstruction of the archaeological site updated to what archaeologists know at some point of the project and the exhibition of the encountered artifacts, together with the information stored in the database. BeArchaeo (Beyond Archaeology[3]) is a digital-born project that records data throughout the entire process of excavation, interpretation, and presentation of findings from a Japanese Kofun, a late 6th-century mounded tomb located in Soja City, Okayama Prefecture, Japan. A semantic database[4] contains comprehensive information on all excavation and analytical activities being carried out. The virtual application has been employed in three physical exhibitions (in Japan and Italy) that illustrate the methodological project.

The paper is organized as follows. In the next section, we describe the related work in the use of virtual reality for archaeology and museum exhibitions. Then, we illustrate the design and implementation of the BeA-ViR application, with some preliminary evaluation after the public exhibitions in Japan and Europe.

2 Related Work

Building an application for the exhibition of an ongoing archaeological project in virtual reality relies on a number of approaches from different fields, namely archaeological reporting methods, virtual reality systems, and virtual museum practices.

Archaeology has always been linked to the data collected during the excavation activities and to their cataloging, management and interpretation [11], and data collection has received a specific attention in Japan ("Japan may be the biggest producer of archaeological data in the world") [32, p.1]. This aspect is due to the nature of the archaeological excavation, which is configured as a specific experience that is 1) unrepeatable and destructive (so, collected data are the only reference to the original site), 2) often distant (because taking place far from the research laboratories), and 3) with limited access (as only some researchers have access to the excavation area) [4]. The wide use of surface survey instruments (photogrammetry and laser scanner), underground survey (resistive georadars and dynamics), topographic mapping (kinetic and static GIS) and various types of archaeometric analyses have added much technicality to data reporting, then increased with networking infrastructures, bringing a necessity of workflow, data management and collaborative research [10]. With reference to 3D models, there have been proposals for the integration of 3D contents with solutions for their visualization into the overall archaeological reporting process. For example, the Interactive Reporting System (IRS) is a web-based tool that relies on 3D web information for the generation of digital interactive reports of excavations [6].

[3] `https://www.bearchaeo.com/`, 15 September 2023.

[4] `https://bearchaeo.unito.it/omeka-s/s/bearchaeo-resources-site/page/welcome`, 15 September 2023.

3D models are useful for communication when integrated into a virtual reality system, with several examples for archaeology. In fact, virtual archaeology is the current logical end of a long path of visualization techniques aimed at filling the gap given by the remoteness of the sites and the limited use of the findings, together with the sketches of interpretation hypotheses [28]. The virtual recreation of sites and artifacts represents a fundamental branch of archaeology and the entire lifecycle of acquisition, processing, data analysis, archiving and dissemination has become integrated [17]. There also are many examples of archaeological research through virtual reality systems. For example, in Japan, Masuda et al. proved the hypothesis of the use of natural light to illuminate the Fugoppe cave, where prehistoric inhabitants carved fascinating engravings [21]. More recently, Elaine A. Sullivan could "peel away the layers of history" at the necropolis of Saqqara, in Egypt, to reveal the changes in the sight lines, skylines, and vistas at different periods[31]. At the crossroad of database documentation and virtual reality visualization is the pioneering Çatalhöyük project, investigating on a Neolithic settlement in Turkey. A number of VR tools, in a few decades, have provided a virtualization of the layer-by-layer excavation, leveraging on 3D GIS data, digital collaborative systems (so-called tele-immersion) and data curation. The study of the spatial and layout data has shifted from the usual 2D mapping to a 3D archive, including the mapping of strata on their XYZ position in the virtual excavation volume [7].

Finally, for our project, we mention the approaches to the virtual exhibitions. For ongoing archaeological projects, this is a peculiar case. Artifacts are still under study and cannot be physically exhibited; moreover, if they undergo invasive archaeometric studies (which, e.g., analyze one section or a sample of it) the digital twin is the only item that is actually the same as the encountered fragment; finally, virtual exhibitions are useful to compare the site artifacts with artifacts belonging to other museums or other sites. Virtual museum idea and technology exist since the early 90's, implemented with various technologies, from precomputed video with decompression, to CD-based multimedia, to more and more realistic interactive 3D graphics [22]. A virtual museum uses information and communication technologies to provide visitors with interactive exhibits, education, and access to historical and cultural information, including (though not always) the presentation of the museum collections through 3D representations of artifacts [30]. The Virtual Museum Transitional Network [9] has provided the terminology and an initial classification system of virtual museums reflecting administrative, descriptive, technical, and use issues. More recent approaches aim at a three-valued classifications, namely content-centric, communication-centric, and collaboration-centric virtual museums (surveyed in [1]), addressing, respectively, content and surroundings, with navigation elements, knowledge transfer and learning linked to objects, and web platforms with shared workspaces and participatory approaches. For example, a hypertext based on geo-referenced archaeological artifacts belongs to the last two categories and has been realized in the project presented here.

Virtual museums can refer single items as well as multiple item collections. Related to archaeology are approaches that implement some format of exploratory or environmental storytelling for the access to the reconstruction sites as well as exhibits. While multiple item exhibitions, together with multiple sites, are commonly available, more typical of the archaeological field are the reconstructions of the sites and single item exhibitions. We report two examples here. Christou et al. [5] have been among the first to propose a reconstruction of a Greek temple in a CAVE setting, with photographs and ground plans used to create an artistic reconstruction for the purpose of engaging visitor. As a single item exhibition, the virtual regain of the destroyed 38m Eastern Buddha figure of the Giant Buddhas in Bamiyan, Afghanistan (destroyed in 2001), integrated into the model of the scanned niche [35]. The virtual model has been the results of several scientific explorations, including an all-season photographic survey of cave structures around the vicinity of the Giant Buddhas, carried out by Japanese missions in the 1960s and 1970s.

3 System design for ongoing archaeological project

Two major notions of the archaeological interpretation concern geo-spatial extents and time intervals related to some site. Archaeology analyzes sites and unearthed findings to form chronological schemes and georeferenced layouts that can purposefully support the reconstruction of the past society. Actually, time as a concept appeared relatively late in archaeology, while space is the fundamental concept that supports research also before the fieldwork starts [8, chapter 6]. In an ongoing archaeological project, it is required to provide access to partial interpretations, that may only address mere technical issues (e.g., some pottery shard is of a non-calcareous material) as well as inform the general public of the current understanding, including both historical background facts (e.g., hypothesis that the provenance of some materials is from some area, because of the comparison with other known artifacts) and the virtual exhibition of the main findings (to engage the community with what is tangibly going on). So, the relation of the current site and the related encountered findings with other sites and findings of the area is relevant for both the researchers and the public, giving relevance to geospatial context.

The BeArchaeo project addresses ongoing activities, excavations of a Kofun burial mound and the archaeological/archaeometric analyses of the findings from the Kofun as well as from other sites of the same area and nearby prefectures provided by local museums. Kofuns are megalithic tombs or burial mounds of the protohistory of Japan (3rd to 7th century CE). They name the Kofun period of Japan (proto-)history. Some of them are famous for their distinctive keyhole-shape and some are inscribed on the UNESCO World Heritage List; their shape can also be circular or rectangular, with several sizes, to a few meters to hundreds of meters, depending of social status of the buried individual. The Tobiotsuka Kofun, excavated in the BeArchaeo project, has a circular shape, with a diameter of 30m.

In this phase, while the excavations are not completed yet and about 200 findings have been unearthed and are being analyzed (mostly pottery shards and some metal weapon fragments, such as arrowheads), the system design has to account for an engaging narration of current status of the project, relying on a geospatial layout for the involved sites and to exhibit the current findings, with related findings from other sites, in a museum setting. The goal is to provide an organization of the materials and knowledge that can engage both the researchers and the general public, by adopting an environmental storytelling, that realizes an immersive narrative experience by evoking pre-existing narrative associations [12], namely the visit to an archaeological site and to a museum, respectively. Interactive overlays and information panels provide basic narration units, while getting close to objects allow to discover its major facts and possibly going deep into the results of the archaeometric measurements and the partial interpretations. The flow chart in Figure 1 illustrates the hierarchical structure: from a main exhibition hall, which reports a geospatial layout connecting real geographic positions of the sites and their diachronic arrangement, the user can access the site reconstruction of the excavated Kofun (site complex exhibition) that consists of the current site, which in turn gives access to the reconstruction of the historical site and a focus on the burial chamber; the reconstruction of the current site given also access to the related virtual museum, with the exhibition of the major unearthed findings with the current interpretations; the current site also includes the excavation records, namely a visualization of the trenches. The related sites and findings are:

- another related Kofun (2), where the reconstruction only addresses the burial chamber (for comparison with the excavated Kofun);
- virtual museums related to multiple-finding exhibitions coming from related sites, including a rough reconstruction of the site (current and historical structure);
- virtual museums related to single-finding exhibitions displaying outstanding pieces, connected for bringing related religious or symbolic values to the excavated Kofun.

This flow chart of information is implemented as a VR application, that traverses many boundaries and borders.

4 The virtual reality application

The general architecture of the VR application (Figure 2) relies on a representation of the archaeological and archaeometric knowledge encoded in a database. The database contains both the descriptions for the general public and scientific data with the corresponding interpretations, addressed by scholars of several disciplines. The VR application relies on these database descriptions, that have been encoded by scientists (after the designer guidance) in the database and the digitally scanned sites and artifacts. The latter are displayed in different environments, as summed up in the flow chart above, with descriptions uploaded

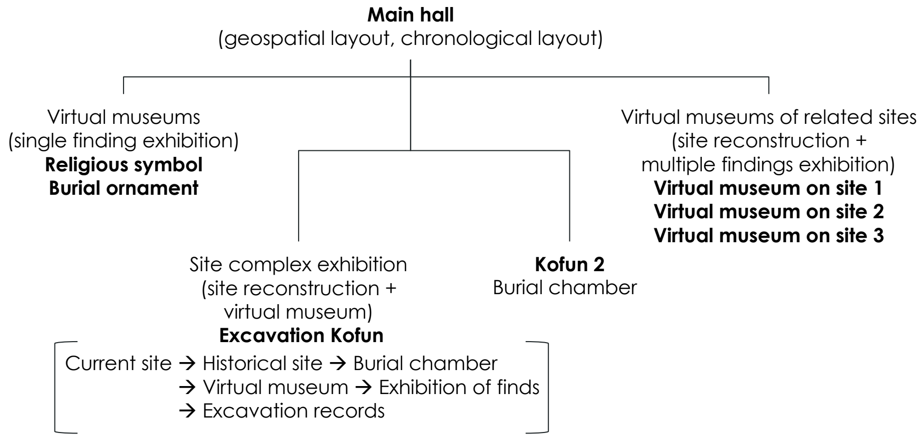


Fig. 1: Flow chart of the BeA-ViR system. Accessible VR environments are in boldface.

from the database. The system is deployed on three platforms, namely a CAVE application, a desktop installation, and the web browser plugin (bottom left, bottom right, bottom middle, respectively, in the figure). It is also possible to explore the database content only, with a simple web interface.

4.1 Traversing boundaries and borders

The BeA-ViR application addresses a number of issues of traversing boundaries and borders. The first is the multi-cultural context of the project. Given its international character and since the installation is displayed both in Japanese and European museums as well as on the web, the application has to reconcile general and specific aspects of Japanese culture. The general aspects concern the geography of the involved Japanese regions and the chronological proto-historic periods of Japan; also, narrative texts have to include introductory notes about Japanese proto-historic features (such as the megalithic mounded tombs). The specific aspects include a focus on the interested local areas of Okayama and Shimane prefectures in Japan (which are significant for the Japanese public, but generally unknown to Europeans), as well as the cultural exchange processes between these areas during the Kofun period. The latter issue was also a key objective of the archaeological/archaeometric investigation: in fact, the travel and trade of materials between communities is one of the interpretation keys for the evolution of civilizations.

Related to this issue are also the multi-lingual features of the application and the multidisciplinary approach to archaeometric investigation: on the one hand, the database of excavations and artifacts includes notes in both English and Japanese, and the text is arranged accordingly to provide a layout of both descriptions; on the other hand, the knowledge representation has to accomodate

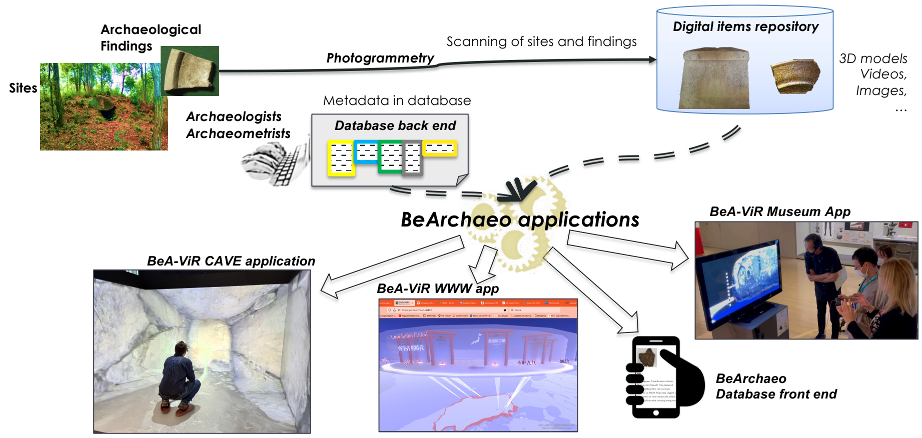


Fig. 2: Software architecture of the BeA-ViR system.

all the several scientific disciplines contributing to the enterprise (e.g., chemistry, physics, archaeomagnetism - see [19]). In Figure 3, we can see the multi-lingual naming of proto-historical periods as well as their mapping onto western calendar indications, and the multi-character-set of sites, connected to the general geographic map of Japan, with a mark of the interested region in West Japan (for local visitors).

The second issue of traversing boundaries is on the characterization of the target audience, which could be the general public, on the one hand, and multidisciplinary scholars, on the other. General public is interested in the major facts about the excavations and findings, especially in this ongoing phase, with attention to methodological issues (e.g., how a finding is analyzed and what are the current hypotheses) and the path to the complete picture (if the composition of the finding is non-calcareous, possibly its provenance is the Kibi area. Scholars are instead interested in accessing the current test results (e.g., images of sections of a pottery shard from the electronic microscope) or comparing the test results of different techniques (e.g., comparing the elemental compositions of two samples). The multi-user experience is implemented by providing both levels in the underlying descriptive database entries. Narrative, wide, and easy-to-understand descriptions for the general public; specific data, including images of the artifacts from Optical and Scanning Electron Microscopy and PLM (Polarized light microscopy), X-Ray fluorescence analysis reports and tomography data, directed to scholars.

Interpretations are associated to appropriate items or a combination of them, reported as a complex item in the database. The interaction metaphor used to distinguish the activation of the two different displays, that is of the visualization of the two descriptive entries, relies on the proximity of the user navigation. In Figure 4, we can see the general and specific descriptions, respectively, for a pottery shard. If the visitor stays at some distance (Figure 4a), the system

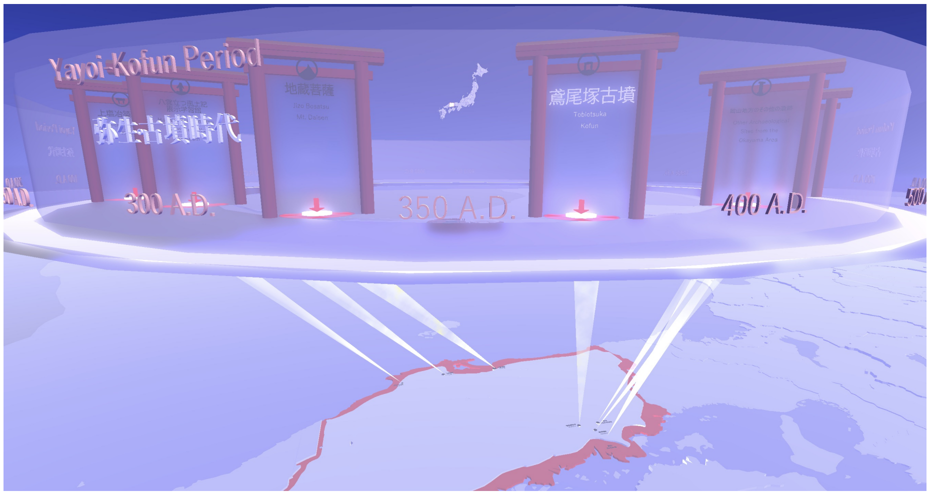
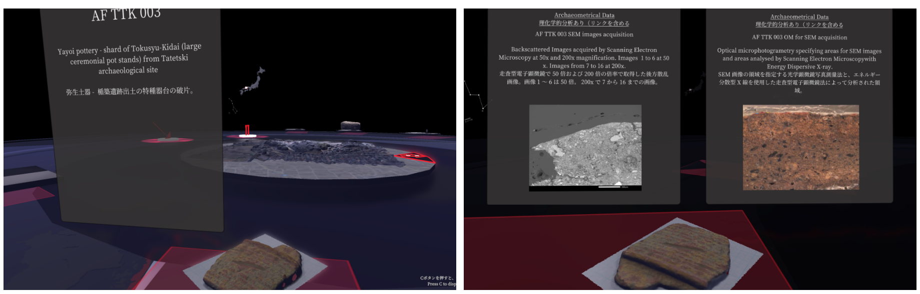


Fig. 3: Main Hall and connection with the geographical region



(a) General audience description for a pottery shard.

(b) Specific archaeometric investigations results for the same shard.

Fig. 4: General and specific descriptions for a finding.

displays a panel with a general description of the finding; if the visitor gets much closer (Figure 4b), the system creates a virtual room with many panels reporting the individual archaeometric investigations on the same finding (in the example case in the figure, two scanned images from sections of the same shard are reported, with the respective descriptions). Panel texts are directly uploaded from the database and reflect the current advancement of the project investigation. They are updated as the project develops, always respecting the directives for their use in the VR application.

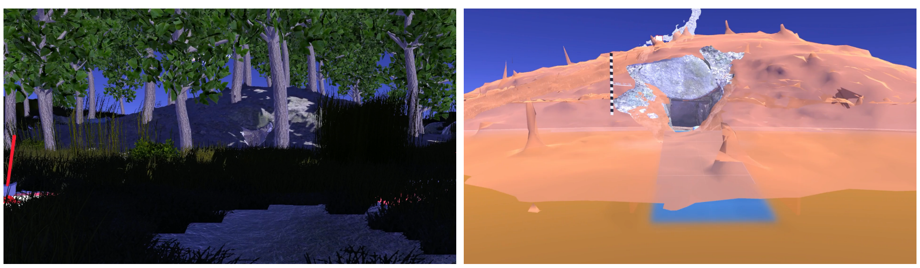
The third issue of traversing borders is the technical deployment of the application, that can be CAVE, desktop, and web (see Figure 2). Though it mainly origins as a technical issue, it has relevant implications on immersion and interaction. The objective is to ease the dissemination, because diverse institutions could be interested in diverse communication formats, and the collaboration between the disciplinary scholars, who may be using different communication modalities and hopefully receive, across versions, a consistent and seamless experience. The application design addresses the three technical deployments. Aesthetics, color, and functionalities are consistent across platforms to create a cohesive experience. The entrance to a virtual room (being it a site reconstruction or a museum exhibition) is realized through a collision with a specific object (step onto a footboard): this metaphor is very immediate for the CAVE environment and is transposed to the desktop and the web implementation; also, it could be employed for future implementations, such as mobile or HMD (traversing further borders). All the technical platforms provide controls for first-person displacement and aerial exploration by soaring or jumping, before falling with gravity. Users who do not want to perform a free exploration can be lead through a "guided tour", which stops at predefined points of interest in the exhibitions.

4.2 The BeA-ViR virtual reality environment

The VR environment that implements these traversals relies on realistic models, for site reconstructions and artifact exhibition, and abstract structures in space, for the virtual museum exhibition. The realistic models exploit the photogrammetry acquisitions that are realized for the digital documentation of the excavation process [15]; the abstract structures are realized as floating horizontal discs, bearing gates to the virtual rooms. The information about what are the geographic locations identified by the gates is expressed by depicting light cones between a map point and the gate. The opening environment (called Main Hall, Figure 3) is a double-encircled disc, spatially located above the Japan region that is of relevance for the project: the inner circle implements the geospatial dimension (with the gates), the exterior circle represents the chronological dimension. Red gates implement the controls for accessing the individual environments mentioned in the flow chart. When the user approaches the external circle, a semi-transparent wall appears, between them and the gates, reporting a timeline of Japanese historical periods and their mapping to western periods: for example, in Figure 3, the Yayoi-Kofun transition period centers on year 300 A.D.. This timeline wall lets users explore the sites (or sub-environments) by using a chorological indexing. While moving around the wall to follow the timeline, gates appear/disappear depending on the existence of the corresponding site in some era. Only the gates that port to sites that were active in the traversed era are represented and accessible on the inner surface.

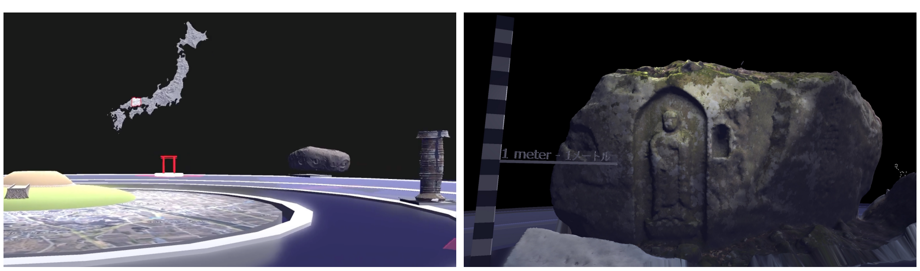
The Main Hall controls the access to the environments through the red gates (or torii). The users can move freely, via gamepad or mouse and keyboard, depending on the implementation platform. The footboards with a downward arrow invite to step onto for accessing the specific environment. The accessible environments split into site reconstructions and virtual exhibitions of findings (cf. the flow chart). Site reconstructions (Figure 5) are explorable 3D models that address both the current status (a) and the archaeological interpretation of the site at historical periods (b). There also are extra artificial structures, marked with unnatural colors, to display interpretive features of the reconstruction (see, e.g., the blue catwalk in Figure 5b, to highlight the passageway to the burial chamber). Again footboards allow the switch between the representations and the return to the Main Hall.

Virtual museums can be multiple finding exhibitions and single finding exhibitions (Figure 6). Contrasting with site reconstructions, these are nocturnal environments, with the floating disc posited onto the geographical location. Multiple finding exhibitions (Figure 6a) host a site reconstruction (current status alternated with archaeological interpretation), encircled by the main findings from that site. The user can travel around the disc and inspect every finding with its story and possibly going deep into its archaeological and archaeometric investigations, data, and interpretation hypotheses. Single finding exhibitions (Figure 6b) position the finding at the center of the disc. The display of the finding is alternated with the display of the site where it has been encountered. All the switches (between finding and environment and between current site and archaeological interpretation) are performed through footboards.



(a) Current status. (b) Archaeological interpretation.

Fig. 5: Navigable Kofun site reconstruction.



(a) Virtual museum for multiple item exhibition. (b) Virtual museum for single item exhibition (notice height measure on the left).

Fig. 6: Environments in the VR application.

4.3 Implementation of the VR application

BeA-ViR has been implemented with Unity in a modular way, so that it could be easily deployed on the three platforms: desktop, web browser, and CAVE. All deployments share the same 3D and 2D assets (with very limited customizations). Starting with the design phase, a domain model and a class diagram were created with UML. This UML schema has driven the implementation and all refinements (which are still ongoing, along with the project). The implementation follows the design and narrative choices as it involves the creation of the three layouts of environments and their associated functions. The main 3D assets are archaeological findings and structures photoscanned through an acquisition pipeline created within the project [15].

Some variants as well as optimization techniques were applied for adapting the application to platforms and improving performance. The desktop version, designed for museum installations, comes with advanced graphics, such as realistic lighting, shadows, and high-definition models and textures. It requires a powerful computer to run smoothly. The WebGL version for the browser has required an optimization (polygon decimation, texture compression, baked lights and some removed shaders), for a smooth execution on the variety of devices and browsers. The highly performative CAVE version did not require optimization on graphics, but a particular coding for the synchronization of the four computers (one per wall) on a local network, with scripts exclusively running on the server process (the front wall of the CAVE) and some functions assigned to the client processes (the other walls).

The presentation of several character sets in the multi-lingual environment, specifically Western and Japanese character sets, was an intriguing problem. An extensive search for a character font has selected the Noto Sans Japanese[5], for the correct display of all characters (including hiragana, katakana, and kanji - a large subset) in the GUIs of the three versions.

Informational panels built after an access to the database entries (set up in Omeka-S CMS to enable a semantic representation [18] [19]). through a Unity implementation of the database Omeka-S API[6]. The library, in particular, enables users to get the metadata for the exhibited objects and and to display custom vocabularies for the archaeometric information addressed to scholars. The implementation currently allows the data to be read only, but it is expected that, in the future, the code will be expanded to also guarantee write options. This could allow multi-disciplinary scholars to work on and annotate details about specific fields in the database, sharing and disseminating knowledge to future users of the application.

[5] `https://fonts.google.com/noto/specimen/Noto+Sans+JP`

[6] `https://github.com/RenderHeads/UnityPlugin-OmekaAPI`, GPL-3.0 License, the same as BeA-ViR

4.4 Preliminary evaluation

At the three public installations of the project, we carried out evaluations of the prototype through the submission of questionnaires (see details in [25]). Evaluations were based on a Likert scale (1-Bad to 5-Great), addressing the overall usability of the system, the effectiveness of the control system, the clarity of design, the archaeological information provided. We also carried out some qualitative observations to assess the overall user experience. 19 people participated to a first evaluation on the desktop application, distributed into 5 age groups (2/12-17, 3/18-24, 5/25-33, 4/34-45, 4/46-60); then, other 7 users, again aged 12 to 60, with various cultural backgrounds, tested the web browser version. The second group also included 3 multi-disciplinary scholars (from the archaeological/archaeometric team), who are, together with the general audience, a target of the project.

About the general public, the results showed that the application and archaeological information were generally well accepted (3.6 average, with 0.9 of standard deviation). However, since a large number of users struggled with gamepad controls (2.5 avg), we developed the "guided tour" functionality, which enables users to see artifacts through virtual jumps, skipping the exploration phase. About the behavioral difference between general public and scholars, we also measured the exploration time of each type of environment (site reconstruction, single finding exhibition and multiple finding exhibition), the display duration for each finding, and the rate of pressing the controls. Both groups have appreciated the overall experience as well as the archaeological information received (both over 4, on the Likert scale). General public did not get the timeline behavior and found hard to coordinate virtual first-person motion (2 and 2.5, respectively). Introducing tooltips were suggested to reduce the likelihood of accidental impacts with item interaction. Experts generally appreciated the system interaction but have required the improvement of the archaeometric information. For example, they appreciated the microscope photos of the artifacts, but proposed to add information about the stratigraphic unit for each finding, to increase the knowledge network and improve the interpretation process. In the case of the 3D reconstructions, they suggested showing the reconstruction stages in a diachronic setting.

Some expert was impressed by the merging of fine 3D representations with detailed archaeometric data, usually kept distinct in projects. In general, unsurprisingly, experts looked for more information than general audiences: on average, the experts pressed the information button a double number of times (38 VS. 19, in a 15-minute session) with respect to the general public, who were usually more focused on the aesthetic/graphic content of the application. Finally, users could correctly recognize the 3-tier environment (site reconstruction, multiple finding exhibition, single finding exhibition), demonstrating the average clarity of the content organization. Users have spent on average more time in multiple finding exhibitions and less time in site reconstruction and single finding exhibitions, which likely need the delivery of more information or some highlighted feature.

5 Conclusions

This paper has presented a virtual reality application for the exhibition of archaeological projects, which merges the reconstruction of the sites and the exhibition of findings in virtual museums, employing interactive 3D graphics in a unified design. The application design takes into account the chronological and the geospatial dimensions, which are common in archaeology. A modular implementation has allowed an easy porting on various devices and platforms. The application, which is applied to the hard case of ongoing archaeological projects, exploits the database entries, set up for the recording of the excavation process and the documentation of findings, guiding researchers in the insertion of appropriate descriptions for the narrative development associated to item entries in the database.

We aim at improving the application for deploying archaeological exhibition of ongoing projects, while contributing to scholars' research via an easy access to database entries, improving the connections. A future virtual museum editor could rely on the application modular structure, to enable curators and scholar to adapt their content to the environment structure.

The case study has been a joint project Europe-Japan on a Kofun burial mound, excavated in Japan, with the encountered findings. Exploiting the virtual reality application, such findings are also related to other sites and findings in neighbor areas. The project is ongoing, with interpretations sometimes including mere hypotheses and incomplete archaeometric data. A preliminary evaluation has been carried out to understand the user reception of an application that merges different uses for the experts and the general public.

The BeA-ViR application traverses boundaries and borders in several dimensions. The virtual environment addresses multi-cultural and multi-lingual issues, related to the Japanese-European public presentations and the deployment in Japanese-English at the same time. It also addresses general public and multi-disciplinary scholars at the same time, introducing a proximity metaphor to let interested people explore the knowledge and hypotheses in depth. Finally, it addresses a multi-platform deployment, with issues related to graphic and interaction designs, in order to ensure a seamless experience across platforms (desktop, CAVE, and web browser).

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