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Cultural Heritage in the Digital Age: Innovative Approaches to Preservation and Promotion (Editorial)

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Cultural heritage is the vital link between the past and the present, ensuring the identity and social cohesion of individuals, communities, and peoples, and plays a crucial role in shaping the future, namely, a more sustainable one. Both tangible and intangible cultural heritage represent one of humanity's most valuable assets, and their preservation, dissemination, and promotion are paramount for safeguarding this shared heritage and simultaneously crucial in confronting the interconnected challenges that define our era, from environmental degradation and global inequality to technological exclusion and escalating humanitarian crises (UNESCO, 2025).

Digital technologies have been used for decades to make cultural heritage accessible to a broader audience, providing tools and platforms for accessing, acquiring, storing, preserving, understanding, and disseminating cultural heritage. In recent years, however, the digital heritage field has undergone a conceptual and methodological transformation, moving from technocentric and archival approaches towards emphasizing the critical role of cultural, social, and institutional contexts in shaping how heritage is represented, experienced, and preserved. The concept of mediation has emerged, we believe, as a key framework, highlighting how interfaces, algorithmics, platforms, and participatory technologies are never neutral, but can actively shape what is included, how narratives unfold, and which audiences are empowered or excluded. Rather than positioning innovation as an end in itself, this evolving paradigm calls for a more reflective and situated integration of technologies that foregrounds epistemic diversity, ethical responsibility, and long-term sustainability in the design and deployment of digital heritage initiatives.

Authors have begun to acknowledge this entanglement between infrastructure and interpretation. Haldrup, Achiam & Drotner (2021), for example, have pointed to the need for "experimental museology", an emerging approach that emphasizes museum-led experimentation, co-design, and co-creation to transform established practices and discourses and that encourages research and implementation of enactive practices to facilitate meaningful visitor experiences by promoting agency through technological appropriation and critical thinking (Rojas, 2020).

Building on the same line of thought, Champion (2022) stresses that Extended Reality (XR) technologies, when anchored in curatorial intentionality and shaped through participatory design, can open space for more nuanced, multi-layered readings of the past within museums. Similarly, Silva & Oliveira (2024, 2025) demonstrate how artificial intelligence (AI) holds the potential to democratize

access and interpretation, namely when applied to crowdsourced photographic data in cultural heritage contexts; nevertheless, they also highlight that such systems can either challenge or reinforce heritage hierarchies depending on how they are designed and deployed.

These conceptual developments also find concrete expression in community-led, virtual-world initiatives intended to address the lack of cultural significance in virtual places, by inviting communities not just to consume heritage narratives but to shape them actively (Champion, 2021) - a move that is both epistemologically and ethically significant. The LOCUS project (Gonçalves, Oliveira & Amaro, 2022), for example, illustrates how collaborative digital placemaking can empower rural communities, support intergenerational knowledge transfer, and foster inclusive heritage imaginaries by co-creating playful and immersive representations of local cultural identity in Second Life, thus offering a compelling alternative to technocentric heritage simulations (Amaro & Oliveira, 2024).

This special issue of the Journal of Digital Media and Interaction (JDMI) is situated within this transformative moment, where digital tools and frameworks are reconfiguring the epistemologies, affective logics, and materialities of heritage, raising new opportunities and deep ethical, conceptual and even practical challenges, demanding balancing innovation with reflection, inclusion with curation, and technological sophistication with long-term sustainability.

As such, this special issue's call for papers outlined a broad yet interconnected set of critical themes, which can be grouped into five thematic axes:

1. Reconstruction and Preservation, addressing both tangible and intangible heritage, digital twins, simulations, AI, and the evolving role of computational tools in archaeological and cultural documentation.
2. Immersive and Sensorial Experiences, including Virtual/Augmented/Mixed Reality, haptics, and biofeedback, to generate new modes of engagement with heritage environments and narratives.
3. Participation and Community Mediation, focusing on collaborative curation, community-driven platforms, and digital tools that promote inclusion, co-authorship, and heritage democratization.
4. Education, Play, and Engagement, encompassing gamified learning, virtual field trips, and interactive experiences that reimagine how heritage is taught, accessed, and shared.
5. Infrastructure, Accessibility, and Ethics, covering IoT-enabled cultural spaces, long-term digital preservation, and cultural heritage digitization's legal, environmental, and ethical dimensions.

These thematic axes were not meant as strict categories but as interconnected zones of innovation and tension that framed the conceptual scope of this special issue and defined the critical ground from which the selected contributions emerged. And, although diverse in focus and methodology, each selected paper responds to one or more of these challenges, offering situated contributions that advance theoretical understanding and practical application.

These contributions are organized around a conceptual arc that begins with material reconstruction and concludes with technical innovation for accessibility, and rather than treating these works as

isolated case studies, we propose to read them as part of a broader, multi-voiced inquiry into how digital technology and cultural heritage converge to reshape how the past is remembered, narrated, and made accessible in the present.

The opening paper by Brittany Glassey explores the reconstruction of missing historical garments using 3D CAD modelling, reflecting on how virtual reconstruction not only supports museum exhibitions but also enables ethical and design-oriented decisions in making substitute garments for tangible display. The paper highlights the potential and constraints of virtual prototyping in sensitive heritage contexts by anchoring the study in the case of a Meiji-period ceremonial skirt.

In the following contribution, Isidre Ot Padilla, Esther Travé Allepuz, Pablo Del Fresno Bernal & Josep Socorregut Domènech present a digital twin developed to overcome physical and interpretive barriers in disseminating an archaeological site, providing researchers and the broader public with new avenues for exploration, while raising critical questions about representational choices and the evolving relationship between excavation and digital simulation.

The next paper, by Diogo Menezes Costa, engages directly with the epistemological implications of modelling archaeological processes. Through the Abade Artificial Archaeological Site project, the author demonstrates how agent-based modelling and artificial inference engines can serve as analytical tools and speculative environments where archaeological hypotheses are tested, refined, and made legible to multiple audiences.

The fourth contribution by Gil Fernandes & Gorete Dinis, examines a small heritage organization's digital presence (and absence), underscoring the unevenness of digital transition and the structural limitations many institutions face. It calls for more grounded, context-sensitive strategies in implementing digital heritage communication.

The last paper by Ian Bacellar & Tarcízio Macedo ventures into the geopolitical dimension of digital media by comparing esports policies in Brazil and South Korea. The paper frames digital gaming not just as entertainment or a cultural industry, but as a potential tool of cultural diplomacy. While not conventionally situated within cultural heritage, this piece expands the boundaries of digital heritage studies by addressing how national narratives and youth cultures are negotiated through digital platforms.

This issue closes with a technical note by Dirk HR Spennemann & Sharnie Hurford, which proposes a method for 3D scanning heritage objects using low-cost mobile technologies, which offers a low-barrier solution for academic and institutional cooperation.

Together, these contributions reaffirm the need to integrate technological innovation with inclusive, critical, and ethically grounded practices in cultural heritage. While they do not exhaust the scope of the field, they collectively signal pathways for future interdisciplinary research and application.

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Virtual Dress, Real Responsibilities: Considerations of 3D CAD Patternmaking to Develop Substitute Garments for Historic Dress Research and Display

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Abstract
This paper explores how 3D virtual reconstructions of historic dress can aid in the development of real substitute garments and serve as a digital visualization tool for display. While virtual reconstruction is presently implemented in other museology fields, the flexible nature of dress suggests a need for an alternative approach, in addition to ethical considerations from the practitioner's involvement. This is demonstrated through the development of a substitute skirt for a circa 1887-1890 Japanese Western-style ceremonial court dress (taireifuku), originally made for and worn by the Meiji Empress. The skirt of the original ensemble is missing and its appearance remains unknown, requiring a substitute skirt to support the original garments when mounted. Following an object-based research approach and advice from specialists in dress history and conservation, the author conceptualized a substitute skirt with the assistance of 3D CAD patternmaking software. The result served as a visual and pattern aid to develop a real substitute skirt that was used with the real taireifuku for two public displays. Further utilization of the virtual reconstruction was demonstrated through the author's development of additional skirt concepts, adapting them for a digital display which was exhibited with the real taireifuku.

Keywords *Historic dress; 3D reconstruction; Digital displays; Virtual heritage; Ethics*

1. Introduction

Costume and fashion design practices strongly link to the understanding of manipulating dimensionality of the body and material. The three-dimensional human form influences how designers transform a commonly two-dimensional material. This relationship defines how designers translate their creative vision from concept to reality, along with how we interact with dress, as wearers and observers. The challenge of using present computer technologies to view real objects stems from our reliance on using static two-dimensional images or restricted video angles on a screen. This digital transition loses the subject's dimensionality, which supported in communicating its original intentions.

Historic dress that originated in a pre-digital world and was intended to be viewed in-situ, naturally struggles to position itself in the digital space while maintaining its sense of dimensionality. When displaying real dress for exhibition, mounting garments on a humanoid form is highly valued for the insight it provides for structure and silhouette (DePauw, 2017). However, observers best understand such benefits in physical exhibitions, where the form can be viewed from multiple angles, providing scale and self-guided learning. When the same form is photographed, only a single viewpoint is captured, limiting this sense of presence and freedom of observation.

An alternative approach to dimension-focused dress display are replicas. Physical reproductions of dress have existed in museums for some time, serving as substitutes while the original remains in storage. Reproductions also have tactile qualities that cannot be replicated virtually, along with providing deeper insight into how the original may have been worn, as it may no longer be in a state of completion or be stable enough for display (Morena, 2013). Garments can also be substituted with extant dress, aiding to complete the image or support the original garments when displayed. However, depending on the subject, creating such reproductions can be difficult or impossible due to the cost of materials, labor and skill required for specialized crafts.

Although three-dimensional (3D) virtual reconstructions of dress lack the tactile qualities of real reproductions, they allow viewers to examine the garment from multiple angles while the real artifact may be unable to view in person (McNulty, 2019). The virtual dress is also native to the digital space, expanding its potential for implementation for other digital mediums and display types. Additionally, there are recognized benefits for non-intrusive research when using representations of real artifacts (Münster et al., 2019), with this offering potential for dress research.

This paper focuses on utilizing virtual reconstructions of historic dress to aid in the development of real substitute garments and as a digital visualization tool. This is demonstrated through the development of a real substitute skirt and virtual conceptual skirts for a Japanese Western-style ceremonial court dress (*manteau de cour*), hereafter referred to as *taireifuku* (大礼服), dated between 1887 to 1890 at the latest. This taireifuku originally belonged to the Meiji Empress, Shōken-kōtaigo (昭憲皇太后) (1849-1914). The real taireifuku was displayed at two public exhibitions; Daishōji Temple (February 2023) and the Meiji Jingu Museum (April 2024). For both displays, the taireifuku was planned to be mounted to resemble a worn garment, but was missing the original skirt, vital for providing visual and structural support. There are no known records of the skirt and how it appeared, meaning the substitute skirt and virtual skirts had to be implemented in a manner that complemented the original taireifuku without creating the assumption that it matched the original.

By referencing existing object-based research frameworks used in dress research, this paper also explores the ethical considerations and risks relating to virtual dress reconstruction from the position of the practitioner. While this developing field of 3D virtual reconstructions already have recognized practical outcomes, it is seldom discussed as to the ethical considerations for the purpose of dress conservation and display. Throughout the project, much discussion was had as to the ethics of digitizing extant culturally significant garments, developing substitute garments with little source material, along with how the original wearer (the Empress) was to be represented by association. Considering such concepts may provide a means to better discern opportunities for including 3D dress reconstructions in material culture research, creating new links and research opportunities between the real and virtual representations.

2. The research gap in virtual heritage and virtual dress reconstruction

Virtual heritage can be described as an experiential medium, combining virtual technologies with cultural heritage, including the reconstruction of data, measurements and observations from reality and the digital space (Champion, 2021b). As virtual heritage is a developing field, intertwined with the rapid development of computer technologies, a recognized concern is a need for regulation. Champion (2021a) notes that virtual heritage faces fulfillment challenges due to the lack of universal standards and no clear agreements on protocols, standards or parameters.

At present, there is no single approach to virtually reconstructing garments that captures all aspects of dress, including flexibility, layering, complex detail, reflection of light, and cost efficiency. Even if this were possible, practitioners cannot conduct the digitization of extant artifacts with the expectation that it is identical to the original. Rather, it is a representation created through mixed interpretations by their own hand and the technology used to digitize it. This is discussed by Champion (2021a) regarding the concept of authenticity in virtual heritage:

> *"Despite improvements in the features, capacity, reliability and precision of 3D formats, there is another, deeper underlying issue: what are these models preserving and what are they communicating to their audience? The question of authenticity is not merely a question regarding the model, but also a question on the intentions of the modelmaker."*

While we cannot control variables specific to the rapid evolution of technology, we cannot disregard our human (practitioner) involvement in transitioning the artifact from reality to virtual, and how we interpret the artifact in this process. By focusing on the practitioner, it may be possible to propose a baseline research approach to guide the development of virtual dress reconstructions in a manner that is adaptable, beneficial, and cost-considerate.

In the study of real dress, there is no singular framework that offers a clean and systematic research approach. Existing approaches have been largely passed down through experience from curator to assistant, having origins in anthropology and art history research (Mida et al., 2015). Recognizing this gap, modern resources have been published that discuss broader object-based research approaches for observing and interpreting dress for display. Mida and Kim's *The Dress Detective* (2015) presents an object-based research framework, structured plainly to help researchers identify and reflect on evidence contained in forms of dress. Additionally, DePauw's *The Care and Display of Historic Clothing* (2017) works to address the practical aspects of managing a costume collection along with theoretical, historical, and display considerations. Both resources reference wider approaches to object-based research, but present their own adaptations to better address specific considerations of dress research.

Although the aforementioned resources are linked to the tangible limitations of real dress, such approaches could be referenced in establishing a baseline research framework for how real dress could be observed and interpreted for digitization and display. While software literacy is needed to develop virtual dress, implementing such skills should also be directed by prior understanding of how real garments look and are made, thus ensuring their virtual interpretation faithfully represents the original (Kuzmichev et al., 2018).

2.1. Virtual reconstruction approaches in consideration to extant historic dress

While dress is a physical artifact, it continuously changes by design, posing challenges for how one should digitize it. Being made to reflect the flexibility of the human form, the way a garment is worn, lit and displayed can alter how it is perceived (Morena, 2013). While dress in museum collections will never be worn again in the interests of their preservation (Liu et al., 2022), recognizing their materiality and purpose to be worn could be a valuable link for how it is represented digitally.

The tools available to develop 3D virtual reconstructions of dress have expanded in the last decade (Liu et al., 2022). One approach utilizes software primarily made for developing 3D models in the gaming and animation industry. While useful, many of these programs are not developed exclusively for making dress and require wider expertise. Another approach involves capturing the real object through photogrammetry, 3D scanning or similar methods, where data is processed through a proprietary 'black-box' technology, generating a three-dimensional model. These technologies have present applications in other museology fields, with ongoing ethical discussions as to the challenges of not being able to examine or verify the processes used to create the 3D result (Dennis, 2021). However, it should be noted that virtual reconstructions excel in fields that rely on the artifact being static in form, enabling the virtual representation to remain as a solid unanimated 3D model. Simulating the active flexibility of real textiles in their virtual representation is more difficult by comparison (Liu et al., 2022).

2D CAD (computer-aided design) software has existed for the apparel industry since the 1970s (Sayed, 2014), its next evolution being 3D. The shift to 3D CAD enables new tools for simulating textiles and garment construction in a virtual environment, primarily intended for product visualization and pattern development in the apparel industry (Choi, 2022). An important shift with 3D CAD patternmaking compared to other 3D tools is that it is intentionally developed for students, designers, and specialists from fashion and garment-related backgrounds. When designers use 3D CAD pattern software to make virtual garments, knowledge of how real garments are constructed and perform is closely referenced, along with software literacy. However, commercial use and education in 3D CAD prioritize implementation for product development or realizing an imagined concept, rather than digitizing an extant garment with a complex history.

While it is valuable to showcase the technical methods and feats computer technologies provide to digitize historic dress, current research in this developing field appear to focus less on the ethical, cultural, and social considerations of these efforts, despite being such vital focuses in the wider fields of museology, conservation, and dress display. While the approaches and considerations to preserve and display real dress are directly linked to it being the original artifact and not a representation, replicas of dress still carry connotations of the original. Morena (2013) highlights that replicas of dress can alter the viewer's perceptions if they are noticeably different and used in frequency, in some cases being seen by as synonymous with the original. Additionally, for cases where the physical original garment is unobtainable or no longer exists, viewers may perceive the image (representation) becoming the original. Therefore, if we are to

justify such technologies in dress research, we should recognize the practitioner's involvement in conjunction with technical literacy. Recognizing this gap is crucial as there is a degree of responsibility involved when representing cultural heritage virtually, as influences from the practitioner's approaches and unconscious biases can further impact how audiences engage with it (Carter, 2021).

2.2. Understanding taireifuku

A notable distinction between regular dress and dress in museum collections is the context for why the latter is considered valuable for preservation. As exploring wider contextual information provides a greater understanding of the artifact in question (Mida et al., 2015), it supports the development of virtual reconstructions, especially one with such a layered history as taireifuku.

Taireifuku originated in the Meiji period (1868-1912), a time of rapid development and modernization in Japan across many fields, including the westernization of formal dress (Nakamura et al., 2012). After being isolated for almost three centuries, Japan opened to the world in 1854. Under the Meiji Government (1868-1912), men in the Japanese court began wearing Western-style taireifuku earlier than women. In 1886, the Meiji Empress was encouraged to start wearing Western clothing for public appearances in preparation for the promulgation of the new constitution on February 11, 1889. This decision reflected her position, and the country she represented to the rest of the world as an equal power. This was expressed in a series of photographs of the Empress taken in June 1889 (figure 1). The Western-style taireifuku in the photo is thought to be the first that was made for the Empress (Bethe, 2020).

Figure 1. Portrait of Empress Shōken. Suzuki Shin'ichi I / National Museum of Asian Art Archives, Smithsonian Institution, The Alice Roosevelt Longworth Collection of Photographs from the 1905 Taft Mission to Asia, FSA_A2009.02_05b (Detail).

Taireifuku was the most formal of court attire, worn for significant events and public appearances. From the 1887 New Years celebration onwards, taireifuku exclusively became the official dress to wear to such events (The Imperial Household Agency, 2014). Today, only three Western-style taireifuku that originally belonged to the Empress are known to still exist (Yoshihara, 2022).

Even though regulations existed for women's Western court dress, they were not stipulated by law (Bunka Gakuen Costume Museum, 2013). The Empress's taireifuku depict an amalgamation of Western trends, along with Japanese aesthetics and skill during this transitionary period (Bunka Gakuen Costume Museum, 1991). They express how the Empress was able to adapt to Western influences while maintaining strong support for local industry and Japanese craftsmanship (Bethe, 2023).

2.2.1. The Daishōji taireifuku

The subject of this research project, referred to as the *Daishōji taireifuku* (figure 2), came into the possession of Daishōji Imperial Convent in Kyoto when it was donated by the Empress in 1909 (Bethe, 2020). It is believed to be one of the earliest Western-style taireifuku to have been made for the Empress, and the earliest known to still exist (Bethe, 2024). After this taireifuku was received by Daishōji, the train was dismantled and cut into two, repurposed as altar cloths (*uchishiki*, 打敷) and later temporarily sewn back together for display purposes.

Figure 2. Bodice and Train of the Daishōji Taireifuku.
Copyright 2014 by Daishōji Imperial Convent. Reprinted with permission.

The whereabouts of the Daishōji taireifuku skirt and its appearance is unknown; only the bodice and train remain of the ensemble (Bethe, 2020). In 2018, The Project for Research, Conservation and Preservation of the Empress Shōken's Taireifuku was launched from a partnership with the Medieval Japanese Studies Institute and Meiji Jingū (Bethe, 2024). Spanning six years, the project's efforts unearthed discoveries pertaining to the construction and history of the taireifuku. While practitioners

from the project were not directly involved with the virtual reconstruction of the Daishōji taireifuku in this paper, their discoveries, thoughts and feedback were invaluable for the research that was conducted and its outcome.

The Daishōji taireifuku possesses conflicting traits compared to other court dress at the time. The fabric reflects a European Neo-Rococo design with a rose motif that is not original to the taireifuku, with the origin of this specific textile being presently unknown (Bethe, 2024). The use of the fabric is uncommon for court dress from this period, with gold work embroidery added across the bodice and edge of the train, over the woven patterning (Bethe, 2023) (figure 3). This gold work technique closely replicates techniques used on men's court dress (Bethe, 2024). While the embroidery appears Western in style, evidence points to it having been made in Japan (Bethe, 2020).

Figure 3. Gold work embroidery on a section of the Daishōji taireifuku train. Captured at Sengiren Studio for the Conservation of Cultural Properties. October 2022.

With the only unaltered part of the taireifuku remaining being the bodice, the information it provides is crucial. The taireifuku bodice features truncated sleeves, reminiscent of the taireifuku in the 1889 portrait. The shaping of the back indicates a bustle, which further aids to inform the approximate date of the taireifuku (Bethe, 2024).

3. Developing a digitization approach based on real costume mounting practices

Prior to developing the substitute skirt, more understanding was needed for how the virtual taireifuku was to be realized. This was gained by the researchers, including the author, exploring how the real taireifuku was to be displayed to the public and how vital it was to be mounted as a dimensional form. While the train pieces were temporarily sewn together for these displays, they were to be separated again afterwards when entering storage, recognizing their evolution into altar cloths as part of the artifact's history (Marschner et al., 2024). Due to the additional work and manipulation of the textile for

this process, this may be one of the last times that the Daishōji train is displayed to resemble a worn garment.

When deciding which type of mount is used to support the garment and provide context (such as silhouette), considerations involve how much of an influence the mount itself should have on the real garment. In a dress mount, the degree of human representation (or the absence of) alters how the garment is perceived (Brooks, 2017), along with how it conveys a sense of the original wearer (Gresswell et al., 2017). In preparation for exhibiting the Daishōji taireifuku, a major consideration involved how the Empress was to be represented in association with the taireifuku. This included the historic context surrounding taireifuku and also how viewers would perceive the Empress as physically wearing the garment.

While contemplating a digitization approach for the taireifuku, a common observation was the possibility of displaying the internal layers and structure of the taireifuku in virtual 3D. This offered a means to showcase details of the garment, which would be impossible with real mounting techniques. While achievable, doing so needed to align with the requirements of the project, along with how it was to be displayed in respect to the Empress. Dress, more so than other artifacts, have a strong association to the individual who wore it, as described by Brooks (2017):

> *"Garments that protected, shaped and presented the body in life can become surrogate bodies in the museum, evoking and memorializing the absent wearer. (…) Wrinkles recall movement; stressed areas suggest the bending of a body that strained – or even burst through – fabric and seams."*

The direct association with the body beneath the dress was a particular concern for this project. Prior to the Meiji era, Emperors and Empresses rarely made public appearances (Yoshihara, 2022). Despite their increased public presence, the Meiji Emperor and Empress remained protected and revered figures. High-ranking ladies-in-waiting would serve as substitutes for garment fittings that were intended for the Empress (Yamakawa, 2016, in Yoshimura, 2023). The House of Worth, who made court dress for a range of international clientele, noted that the Meiji Empress was their most difficult client to dress, due to extreme restrictions regarding how much of the body and décolletage could be exposed (Trubert-Tollu et al., 2017). The historic representation of the Meiji Emperor and Empress carries influence today, especially when expressing the physical presence of such esteemed figures. This posed a particular challenge for the taireifuku bodice, being closely shaped to the human form by design. In consideration of this context, the research team decided to develop an archival 'floating mount' for the bodice. Using a flexible yet sturdy felt to create a historically accurate silhouette (Esguerra, 2024), it would provide stability and minimize handling for future displays. This archival mount now rests inside the bodice, concealing and protecting the internal construction of the garment. The mount also ensures that viewers today only observe what was intended to be seen by the public when the Empress originally wore the taireifuku. The bodice being form-fitted benefitted this approach, as the mount reflects how the garment naturally wants to rest. The mount was constructed from direct measurements of the bodice (Esguerra, 2024), rather than the body beneath, meaning it references how it may have rested, but does not over-insinuate the human form itself.

Additionally, a removable detailing was included to resemble a diaphanous blouse worn under the bodice, as seen in the 1889 portrait of the Empress. Often these were worn with taireifuku, aiding to conceal the exposed chest and arm openings (Bethe, 2024).

Recognizing my position as the practitioner, there was a degree of responsibility needed for the virtual taireifuku to align with the historic context of the taireifuku, in a manner that was informative to the project's needs, yet considerate to the original wearer. In reflection of the actions made by the research team, I opted for using an invisible mannequin, with the dimensional form of the bodice mirroring how the real garment appears on the felt mount. As this would expose the internals of the virtual taireifuku when viewed from various angles, I simplified or omitted such details from the final 3D renders, removing the attention from these areas when displayed. This prevented viewers from seeing the internal structure, thus protecting the privacy of the real garment that it is a representation of. A diaphanous blouse was also virtually constructed to serve the same purpose as with the real taireifuku, but was treated as a separate element and used exclusively for display purposes.

3.1. Constructing the Daishōji bodice and train

I used CLO, a 3D CAD patternmaking software, to virtually reconstruct the Daishōji taireifuku. It was selected based on the practical needs of the project, specifically flexibility, as the substitute skirt would likely alter the shape and position of the extant garments. Additionally, freedom of exploration was needed to determine how to pleat the waist of the train, as this was impossible to observe with the real taireifuku until the exhibitions commenced. At the time, the virtual taireifuku served as closest visual reference for how the taireifuku was to appear when exhibited, providing an opportunity to explore multiple avenues before committing to the final display.

I referenced precise measurements of the bodice and train, provided by the research team, drafted these into CLO as a 2D pattern and then draped them in 3D. I used high-resolution photographs to document each section of the bodice and train, which I adapted to create textures for each panel. From these photographs, each layer of the fabric and embroidery were digitally separated and given individual properties to simulate the fabric and the gold work embroidery (figure 4). This method supported replicating the luster of the silk fabric more precisely, which the research team and myself deemed to be crucial as it is a key visual characteristic of the taireifuku.

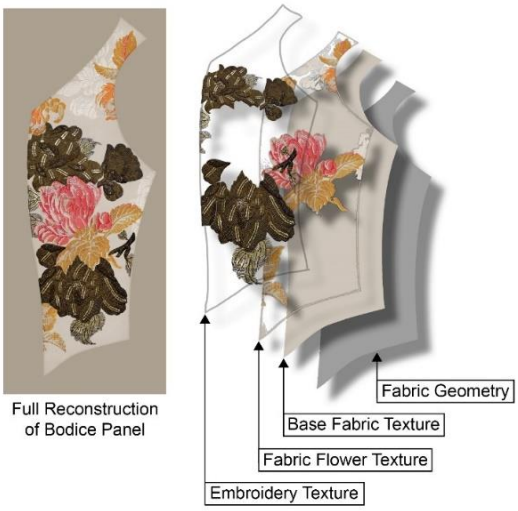

Figure 4. Diagram showing the layers of a panel from the digitized Daishōji bodice.

To support experimentation for pleating the taireifuku train at the waist, I added a temporary translucent skirt (figure 5). While knowledge is lost for the original construction and pleating of the Daishōji taireifuku, remaining clues indicate it may have been lined and padded in a similar means to a circa 1900 taireifuku also worn by the Empress, now in the collection of the Bunka Gakuen Costume Museum (Bethe, 2020). Because the other train tapers to the waist, adaptations were made to the pleating for the virtual taireifuku, as the Daishōji train is rectangular in shape with no taper.

Figure 5. Bodice and train of the Daishōji taireifuku virtual reconstruction, with a temporary skirt.

During development, not all information I needed from the real garment was clearly legible through measurements and photography alone. This was especially the case for the detailed construction of the bodice. When observing real garments in object-based research, making drawings provides a deeper record of details that can be interpreted more clearly by the researcher (Mida et al., 2015). While virtual garments are not constructed in the same manner as real garments, these details need to be digitally represented in a way that is believable to the real garment. While the internals of the taireifuku were omitted in the final renders, I still utilized them in development to support the accuracy of the external appearance. By making technical

drawings of the taireifuku inside and out (figure 6), this minimized the risk of overlooking them later in development, especially when the detailed fabric and embroidery made the virtual garment more visually complex. Furthermore, this deeper understanding of the bodice construction supported how the substitute skirt was to be positioned with the existing garments, especially regarding the angle of the boning, which was essential for creating the bustle shape.

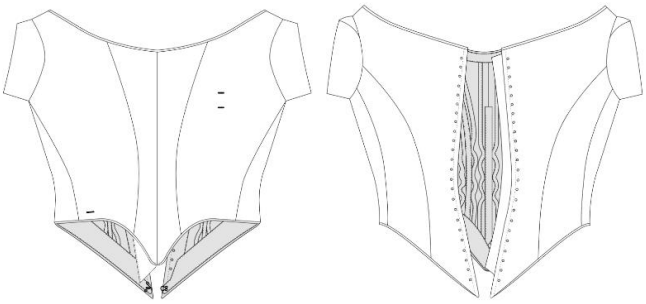

Figure 6. Technical drawings of the Daishōji taireifuku bodice.
Left: Front view.
Right: Back view.

4. Developing the substitute skirt for the real Daishōji taireifuku

This project revolved around the undeniability that we do not know what the real skirt looked like and depending on how the substitute skirt is used, it may alter how the taireifuku is interpreted. To address this, I focused on gathering extensive contextual research, collaborating with experts and scrutinizing how the substitute skirt was to be positioned alongside the Daishōji taireifuku.

The remaining two extant taireifuku offer tangible information for the skirt; however, these date later, circa 1900 (Yoshimura, 2023) and 1912 (Kawai, 2020) respectively. The circa 1900 taireifuku does provide a reference for the length of the skirt, but stylistically differs from what would have been worn in the late 1880s. A more period-accurate reference for the skirt's possible visual appearance is the skirt worn in the Empress's 1889 portrait, but this is difficult to observe as it no longer exists.

In February 2023, the 8.1 Transboundary Fashion Seminar was held at Bunka Gakuen University in Tokyo, to explore the wider history of the Empress and court dress, including discussing the preservation and display of the Daishōji taireifuku (Takagi, 2023). Attendees from Japan and abroad participated, having involvement with The Project for Research, Conservation and Preservation of the Empress Shōken's Taireifuku. These included from Bunka Gakuen University, the Kyoto Costume Institute, Historic Royal Palaces (United Kingdom) and the Los Angeles County Museum of Art (United States of America). Multiple discussions led up to the final session involving a collaborative workshop, where I developed the substitute skirt in CLO, based on real-time feedback from the participants.

During the seminar, the need for a late 1880s bustle for the skirt continued to be emphasized. Additionally, the skirt needed to be elongated at the back with its own train, as this would support the positioning of the taireifuku train over the bustle to the floor. Available pattern resources for Western-

style 1880s skirts were difficult to reference without requiring adaptations as they were not for court dress, instead being for day or evening dress.

From discussions during the seminar, the participants selected two skirt patterns as primary references. Both patterns were from Janet Arnold's Patterns of Fashion series, with adjustments needed to reflect the needs of the taireifuku train. These patterns were an 1882-83 dinner dress to reference the skirt shape, along with the apron pattern from an 1887-89 dinner dress (Arnold, 2022). The apron served as a reference to the 1889 portrait skirt as it appears to have a draped panel over the front underskirt, along with being stylistically accurate to the period.

The participants also discussed whether the original skirt would have been patterned and if the substitute should reflect this. A known practice of European court dress of that era involved balancing a complex or patterned bodice and train with a more simplistic skirt – and vice-versa, a patterned skirt with an un-patterned remaining ensemble (Marschner, 2023). Due to the unique context of taireifuku possessing both European and Japanese aesthetics, it is difficult to determine if the Daishōji taireifuku followed the same considerations so precisely. However, this was reflected in the Empress's 1889 portrait, where the skirt is patterned, but the bodice and train are not, with the exception of sectioned embroideries on the bodice.

An additional reason for the substitute skirt to not use patterned fabric was to prevent the skirt from becoming a distraction when viewing the real bodice and train of the taireifuku, increasing ethical concerns for misinterpretation by the hand of the practitioner. Substitute garments are intended to complement, not dominate, enhancing the viewer's understanding of the garment as a period piece and how it may be interpreted (DePauw, 2017). To best complement the taireifuku in this respect, the textile of the skirt was made of silk with a slight luster and was dyed to match the off-white base of the taireifuku.

During the final session of the Transboundary Fashion Seminar, the participants made collaborative drawings on a whiteboard (figure 7). These drawings, in addition to Janet Arnold's patterns informed my development of the substitute skirt, while everyone observed and provided feedback in real time (figure 8). The workshop concluded with a plan towards constructing the real skirt in the following week, using the virtual taireifuku and skirt as a visual guide for its expected appearance when mounted with the real bodice and train. The virtual skirt also provided a base for developing a sewing pattern to make the real skirt.

Figure 7. Drawings made during the collaborative workshop, by Joanna Marschner. Captured at Transboundary Fashion Seminar 8.1: Manteaux de Cour of the Meiji Empress: Conservation, Preservation, and Display. Bunka Gakuen University. February 4, 2023.

Figure 8. Live feed of the Daishōji taireifuku substitute skirt being developed, using CLO. Captured at Transboundary Fashion Seminar 8.1: Manteaux de Cour of the Meiji Empress: Conservation, Preservation, and Display. Bunka Gakuen University. February 4, 2023. https://transboundaryfashion.wordpress.com/2024/04/02/seminar-8-1-manteaux-de-cour-of-the-meiji-empress-conservation-preservation-and-display/

In the week following the seminar, I continued to make adjustments to the virtual taireifuku and skirt in Tokyo, then sent visuals and pattern data to the team in Kyoto, who were creating the real substitute skirt. Primary revisions focused on the apron, which required several refinements (figure 9), as Arnold's reference pattern draped too low on the skirt. It appeared unbalanced considering the Empress's stature, who was believed to be no taller than 150 centimeters (Yoshimura, 2023). Additionally, the bustle needed greater prominence. The final skirt featured an adapted apron pattern to accommodate these considerations (figures 10, 11).

Figure 9. Various apron explorations during development, outlined in red.
Left: Arnold's original apron pattern, deemed too long.
Centre: Adapted apron based on feedback, deemed too short.
Right: Final adapted apron design.

Figure 10. The final virtual substitute skirt, with the virtual taireifuku bodice and train.

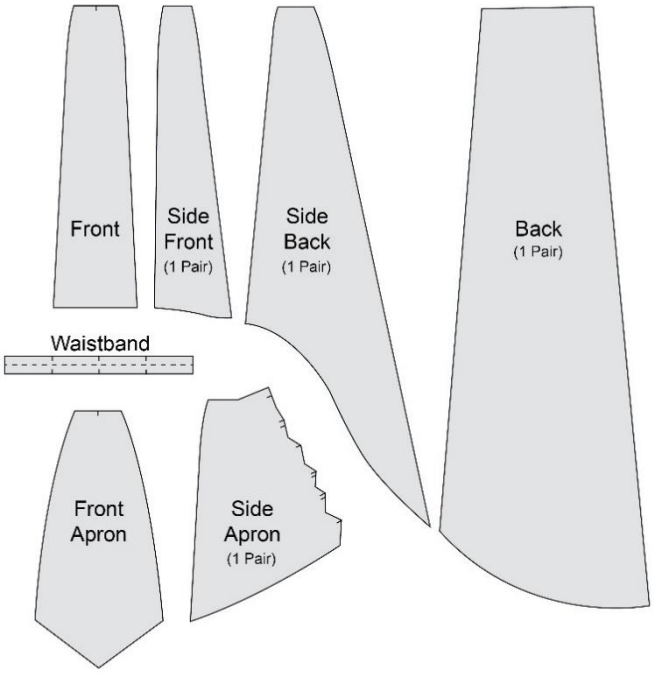

Figure 11. Flat pattern of the final substitute skirt.

The dimensional mount of the Daishōji taireifuku with the substitute skirt was implemented for both the exhibition at Daishōji and at the Meiji Jingū Museum (figure 12). A special hip mount was also constructed for the taireifuku, which supported in making the period-accurate bustle appearance of the late 1880s (Esguerra, 2024).

Figure 12. The Daishōji taireifuku, with the substitute skirt on display. Captured at the Meiji Jingū Museum. April 4, 2024.

5. Developing virtual concept skirts for exhibition

An opportunity that emerged during the project was the possibility to explore additional skirt concepts without the end-goal to have a real-life replica be made. The real substitute skirt addressed structural and silhouette concerns for mounting the taireifuku, but providing only one skirt concept to the viewer may suggest it represents the most likely appearance of the original, despite that not being the case.

Historically and still today, museums focus on the materiality of artifacts and the physicality of observing history from within the museum space (Ciolfi, 2021). Recently there has been a noticeable shift towards prioritizing visitor experiences over object-centeredness (Wu et al., 2022). This shift can benefit virtual heritage, as the intention is similar in terms of providing informative and more personal experiences for visitors observing such objects (Ciolfi, 2021). However, when only part of the real artifact remains, it creates a grey area regarding how technology could or should be used to express what is missing and how it may have appeared originally.

The research team decided that three virtual skirt concepts would be made and included in a four-minute video, used for the exhibition at the Meiji Jingū Museum (Glassey, 2024). The video also showcased other features of the Daishōji taireifuku that were missing or difficult to notice. The adaptability of the virtual taireifuku was invaluable in providing this insight, especially since it was unreasonable to manipulate the real garment due to its delicate nature and incomplete state. Utilizing digital tools alongside the real artifacts in display can provide a more mindful experience of ‘augmenting’ the tangibility of an object, rather than substituting it, finding this balance can be what provides a deeper experience for visitors (Ciolfi, 2021).

The three virtual skirts were based on different historic sources, one having more significant focus, being inspired by the skirt in the Empress's 1889 portrait. The two remaining skirts were more distant interpretations of other garments. The first being a skirt from a circa 1886 chureifuku, another form of court dress worn for evening parties and banquets (Bunka Gakuen Costume Museum, 2013). This chureifuku was originally worn by Princess Kitashirakawa (1862-1936). Made by Max Engel, it was to be displayed as part of the same exhibition (Kasumi Kaikan, 2024). The other skirt would draw inspiration from a court dress worn by Margherita, Queen of Italy (1851-1926), in a portrait painted by Pasquale Di Criscito in 1878. I adapted these skirts to reflect the frame of the Empress, while simplifying the styling. The three different skirts were selected due to their variance in design, supporting the notion that we cannot be sure of the true appearance, but through this knowledge gap we can explore a range of potentials linked to historical sources.

Discussions arose regarding earlier ethical considerations relating to whether the virtual skirts could be patterned or remain simplistic, like the real substitute skirt. The dominant consensus among the research team favored that more complex skirt concepts could be explored virtually only. Observers may better differentiate them as concepts as the video was to be exhibited with the real taireifuku, itself having a larger presence as the focus of the exhibition and serving as the primary reference. This decision was considered as a specific exception regarding the context of the exhibition and may have been treated differently if the real taireifuku was not in the presence of observers.

During the completion of this project, I raised concerns regarding how a practitioner would approach adapting these existing skirt designs in a manner that was considerate to the project's intentions, without introducing personal factors, such as bias. While the substitute skirts were based on historical sources, a degree of creative involvement was necessary to make changes so they could 'suit' the Daishōji taireifuku. There are existing ethical discussions in the field of archaeology as to the amount of interpretation that is required by the practitioner when developing 3D reconstructions, as the result can be unclear to observers as to where the line is between the original data and the practitioner's creative involvement to create a more complete, yet uncertain image (Barratt, 2021). While these considerations are difficult to measure and evaluate, the research team discussed this extensively. In dress research, depending on the researcher's background, different skillsets and preferences arise, whether it be related to the aesthetic, function, or other aspects of dress (Mida et al., 2015). As the research team involved with the Daishōji taireifuku was international, with varying expertise and backgrounds, this range of perspective was a unique and valuable asset for this project. The skirts were developed by creating and sharing dozens of skirt concepts over several months with the research team, with my goal to work towards an agreeable conclusion from the feedback that was received and discussed. The final three outcomes from this process were used for the exhibition video (figures 13, 14, 15). When presented to the public, the virtual skirts were accompanied by images of the original reference garments, along with statements noting these depictions were intended to express how the skirts and other attributes of the taireifuku may have been used, but did not claim to be true to reality.

Figure 13. The virtual Daishōji taireifuku, with a concept skirt inspired by the Meiji Empress's 1889 portrait.

Figure 14. The virtual Daishōji taireifuku, with a concept skirt inspired by Pasquale Di Criscito's 1878 painting of Margherita, Queen of Italy.

Figure 15. The virtual Daishōji taireifuku, with a concept skirt inspired by the circa 1886 chureifuku worn by Princess Kitashirakawa.

6. Conclusion

Highlighting the importance of this project, built on the aim to present the Daishōji taireifuku as a three-dimensional form, Joanna Marschner shared her reaction after observing the Daishōji bodice for the first time (Marschner et al., 2024):

> *"Having just spent a week looking at wonderful – but mainly flat – textiles, the great moment was when out of the little storage room (…) came a beautifully paper-wrapped parcel. It was undone, very carefully and with a good deal of ceremony – out of it came the little boned bodice. (…) For me this evoked the person, in its three-dimensionality. As a monarchical historian, straight away I was back in the middle of the nineteenth century, already beginning to think about an Empress who in other circumstances could have met Queen Victoria, a figure from history with whom I was so familiar."*

The Daishōji taireifuku is an intricate and greatly treasured artifact, evident in its construction and history, with its mysteries making it an enigma to study. The Project for Research, Conservation and Preservation of the Empress Shōken's Taireifuku exemplified what an international team of practitioners can accomplish, contributing a range of specializations and skills. Developing the substitute skirts represented only part of the wider picture, greatly benefitting from research and advice provided by others.

The rich historic context of the Daishōji taireifuku provided a unique perspective into the ethical and cultural considerations necessary for this project. While it benefited from an international team of specialists, this also revealed how stylistic preferences and approaches differed between individuals. This cultivated a highly collaborative environment to discuss what was most suitable for the context of the exhibition and connection to the Meiji Empress. Understanding these needs and concerns aided in informing a digitization approach for the Daishōji taireifuku and subsequent skirt concepts, along with how they were displayed to the public.

Even with the extensive research available for this project, it could not replace verifiable evidence of how the skirt would have originally appeared, which was impossible to determine. We had embraced that this was something that we could not replace or claim that it would have appeared a certain way. This posed a particular challenge, as the dimensionality of the Daishōji taireifuku was a priority for its display, requiring a skirt for support. The specific needs of this project guided a unique approach to reconstructing the taireifuku and developing substitute skirts, presented in this paper to generate thought for how a practitioner may need to adapt to the unique needs of other forms of dress that have their own complex stories.

The effectiveness of the virtual substitute skirt developed from the Transboundary Fashion Seminar was observed through the clear visual similarity between the virtual concept and the real result. While the skirt was conceptualized during the collaborative session, the final virtual and real skirt were constructed by different individuals, over long-distance communication. The real substitute skirt provided structural and silhouette support, improving observers' understanding of this period dress, with the virtual skirt performing as an assistive tool to achieve this result.

A notable observation from this project is the high commitment of time and resources needed to achieve complex virtual reconstructions such as the Daishōji taireifuku. This type of in-depth approach

is unlikely to be feasible on a large scale for digitizing museum collections, but offers potential for use in specialized research projects. This highlights the potential benefit of developing a practitioner-focused, object-based research approach to digitizing dress. This approach could be adapted for other projects, developing our insight as practitioners to realize new opportunities when observing real dress and seeing how digitization may benefit it.

While ethical considerations were explored and referenced in wider discussions throughout the project, a limitation of this research was that it lacked a means to evaluate public perception when the exhibitions commenced. Feedback throughout the project was provided by specialists with their own experience of preserving and displaying dress. This research is presented with the intention to provide an early insight into how object-based research frameworks of real dress could be implemented in virtual dress research, aiding to establish this developing field. Even as the technologies we use inevitably evolve, the benefits of dress and material culture research remain prevalent. By allowing the artifact to guide how its story should be told, we can find means to communicate those stories with the tools we have at present.

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A Digital Twin for the Monastery of Sant Genís de Rocafort, Martorell, Barcelona: Experiences in Research and Dissemination

(Un gemelo digital para el Monasterio de Sant Genís de Rocafort. Martorell, Barcelona: Experiencias de Investigación y Divulgación)

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Abstract
The Monastery of Sant Genís de Rocafort (Martorell, Barcelona) has been the subject of archaeological excavation for over a decade. This work has uncovered Romanesque structures and some earlier elements, significantly enhancing our understanding of this monument, which is listed as a BCIN (Cultural Asset of National Interest), and its history. However, the site's location and accessibility challenges have limited the opportunity for certain audiences to visit and learn about it. In this context, the research team has developed a digital twin of the monastery, a three-dimensional recreation that offers significant potential both for heritage dissemination and basic archaeological research. This project has enabled precise documentation of the structures and created an accessible resource that brings the monastery to a wide range of audiences while also allowing us to experiment with different reconstruction hypotheses. The process of creating the digital twin has raised a series of methodological and conceptual challenges, such as the selection of technological tools and decisions about how to present the site's narrative. This article reflects on the experience gained throughout this process, exploring the implications of these decisions for both archaeological research and cultural dissemination.

Key words *3D Documentation; Virtual Reconstruction; Archaeology; Built Heritage; Middle Ages*

El Monasterio de Sant Genís de Rocafort (Martorell, Barcelona) ha sido objeto de excavación arqueológica desde hace más de una década. Los trabajos han puesto al descubierto las estructuras románicas y algunos elementos previos a su construcción que han incrementado significativamente el conocimiento que tenemos sobre este monumento catalogado como BCIN y de su historia. Sin embargo, las condiciones de acceso del yacimiento y su situación han limitado la posibilidad de que una parte del público general lo visite y conozca. En este contexto, el equipo de investigación ha desarrollado un gemelo digital del monasterio, una recreación tridimensional que ofrece un gran potencial para la divulgación del patrimonio y la investigación arqueológica de base. Este proyecto ha permitido documentar las estructuras de forma precisa, crear un recurso accesible que pone el monasterio al alcance de audiencias muy diversas y que nos debe permitir experimentar con distintas hipótesis de reconstrucción. El proceso de creación del gemelo digital ha planteado una serie de desafíos metodológicos y conceptuales, como la selección de herramientas tecnológicas o las decisiones sobre cómo presentar la narrativa del lugar. Este artículo presenta reflexiones sobre la experiencia acumulada durante este proceso, explorando las implicaciones de estas decisiones tanto para la investigación arqueológica como para la difusión cultural.

Palabras clave *Documentación tridimensional, Reconstrucción virtual, Arqueología, Patrimonio edificado, Edad Media*

1. Introducción

A lo largo de 2024 se ha llevado a cabo un proyecto que tenía por objetivo la generación de un recurso digital que —con carácter inmersivo— facilitara la accesibilidad a un bien patrimonial de primer orden, y su conocimiento y puesta en valor para un público amplio. Nos referimos al monasterio de Sant Genís de Rocafort (Martorell, Barcelona), situado en lo alto de una colina que preside el principal lugar de paso entre la ciudad de Barcelona y las tierras interiores de Cataluña, siguiendo el itinerario de la antigua Via Augusta. A través de un estrecho congosto en la Cordillera Litoral por el que discurren las principales vías de comunicación entre Barcelona y la Cataluña central, el municipio de Martorell se abre hacia la comarca del Penedès en la confluencia entre los ríos Llobregat y Anoia. Lo que hoy en día es un denso nodo en la red de carreteras y vías férreas conserva afortunadamente algunos de los vestigios del paisaje medieval y, en particular, algunos elementos que nos permiten investigar su configuración en tiempos pasados, cuando la antigua iglesia de Santa Margarida y el Monasterio de Sant Genís de Rocafort se configuraron como elementos articuladores de un priorato fundado a principios del siglo XI (Baucells Reig, 2007) (**Figura 1. Mapa de situación**).

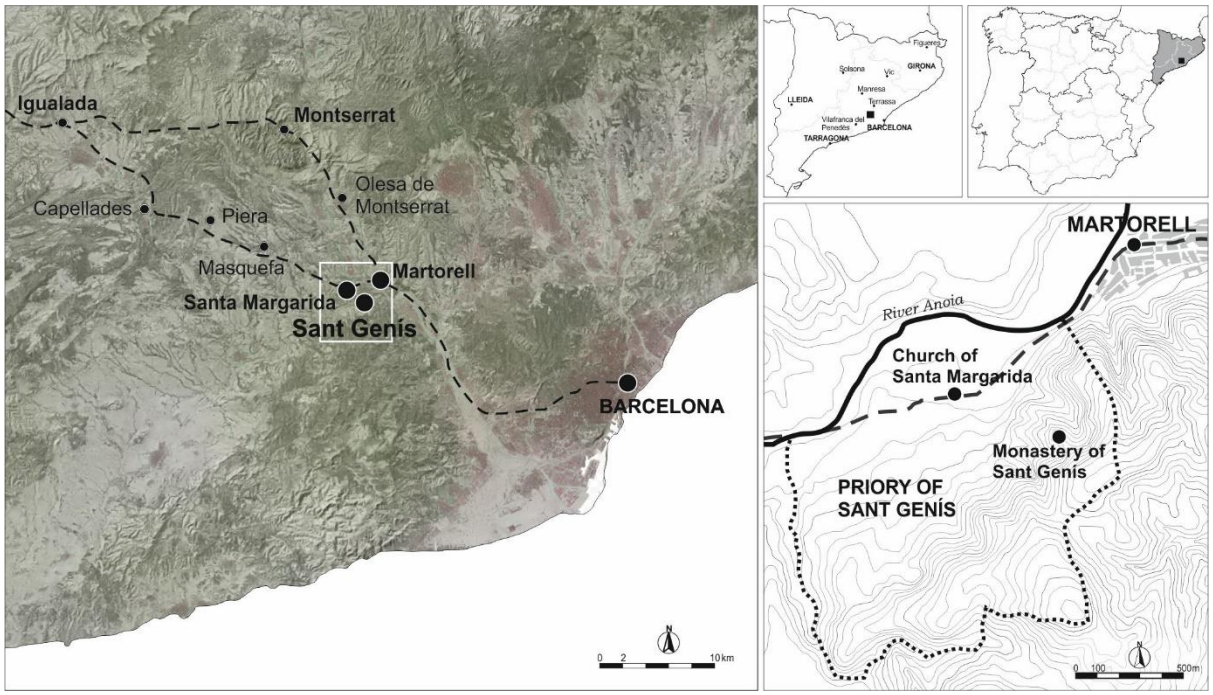

Figura 1. Mapa de situación
del monasterio de Sant Genís en relación con el territorio del priorato, las principales vías de circulación y su ubicación en Cataluña y la Península Ibérica. Base cartográfica basada en datos LiDAR proporcionados por el Instituto Geológico y Minero de España (IGME).

El monasterio constituye un yacimiento arqueológico excavado desde 2010 y, de manera ininterrumpida desde 2014, del cual sólo se conocía la iglesia situada en el punto más alto de una pequeña colina a 201 m sobre el nivel del mar. Los trabajos de excavación posteriores dieron a conocer la complejidad estructural de un complejo bastante mayor de lo que se conocía, con dependencias monásticas de diversa índole que quedaban resguardadas por una muralla que cercaba el promontorio en su parte superior. Después de una década de trabajos arqueológicos, existían numerosas razones que reclamaban una solución digital para la preservación de un monumento fuertemente expuesto a la

erosión por razones atmosféricas y climáticas, sin menoscabar la incidencia que a lo largo del siglo XX tuvo en él la acción antrópica.

En este trabajo presentamos algunas reflexiones surgidas a tenor de la elaboración de un gemelo digital del monasterio y su explotación posterior, todavía en curso, acerca de los criterios científicos que han motivado la toma de decisiones y, por ende, los resultados obtenidos. El gemelo digital de Sant Genís supone en sí mismo un elemento patrimonial de primer orden que nos permite llegar a un público amplio, explorar nuevos lenguajes de comunicación sin comprometer el rigor de la investigación científica.

2. El yacimiento y su estudio: contexto y metodología

Al iniciar los trabajos, del monasterio de Sant Genís de Rocafort sólo se conocía la iglesia situada en el punto más alto de una pequeña colina a 201 m sobre el nivel del mar en la que se distinguen hasta tres terrazas sucesivas que escalonan su orografía. El bien había sido declarado BCIN en 1949 por circunstancias fortuitas: Cuando en aquel año se reconoció en el catálogo de bienes culturales de interés nacional a todos los castillos del territorio, Sant Genís de Rocafort, que entonces era conocido como tal, se benefició de dicha protección. La investigación posterior (Pladevall, 1970) certificó a partir de los años 1970 que el conocido como Castillo de Rocafort, erróneamente atribuido a los templarios en algunas fuentes (Clopas, 1945), no era tal, sino que se trataba de un monasterio de obediencia benedictina dotado en 1042 por los señores de Castellvell, en el contexto de formación de las estructuras feudales. Pese a su elevado grado de protección, el edificio permanecía en un estado de conservación muy precario a principios de este siglo y amenazaba ruina, lo que propició la redacción de un plan director y el inicio de los trabajos de recuperación. La estructura de la iglesia, cuyo ábside había sido víctima de una voladura controlada para su explotación como cantera, fue consolidada en la parte superior para frenar la abertura progresiva de los muros laterales, que hubiera culminado en su hundimiento.

2.1. La excavación arqueológica del complejo monástico

Consolidado el edificio principal los trabajos arqueológicos se centraron en las tres terrazas circundantes que definen un espacio a distintos niveles que define un recinto delimitado por una muralla. Sobre la terraza superior, se eleva la iglesia, situada en el área norte de la terraza y al sur, adosado a la pared meridional, un claustro de forma poligonal se adapta a la morfología de la colina. Desde el claustro, una imponente escalinata monumental da acceso a los edificios de la terraza intermedia y al piso superior de los de la terraza inferior. A tenor de los restos arqueológicos recuperados, la terraza inferior habría albergado un complejo edificado a dos niveles: una planta baja a nivel de circulación de la terraza y un piso superior cuyo nivel de circulación se sitúa a la altura de la terraza intermedia, desde la que se accede a dicho espacio superior (**Figura 2. El conjunto arqueológico**).

Figura 2. El conjunto arqueológico
Vistas de la fachada norte con la muralla delimitando el recinto (izquierda), de la fachada oeste (centro) y de las dependencias monásticas sobre la terraza intermedia (derecha). Fotografias: Centre d'Estudis Martorellencs.

En la terraza intermedia, tres habitaciones se distribuyen exclusivamente sobre la vertiente sur, puesto que el espacio de circulación de dicha terraza al norte es especialmente limitado. De estas tres habitaciones, los restos hallados en la habitación central nos permiten sugerir con cierta seguridad su función como cocina monástica. La presencia de un hogar de cierta envergadura y de los restos de una pila para el lavado y trasiego de productos, así como algunas canalizaciones de desagüe sugieren dichos usos de carácter funcional. Los restos más parcos, con evidencias de algunos artefactos metálicos, entre ellos una herradura, nos lleva a sugerir que la habitación situada al este habría tenido posibles funciones de almacén. Desconocemos el uso que la comunidad dio a la habitación occidental, que es algo más suntuosa que las demás, con una escalera propia de acceso desde la terraza superior y paredes encaladas.

Los restos de la terraza inferior se conservan de forma muy precaria, dada la intensa explotación del espacio como cantera. Los resultados obtenidos hasta ahora apuntan que probablemente el espacio norte de esta terraza inferior fuera un espacio muy poco edificado. Al norte, los sondeos realizados han dado a conocer los rasgos constructivos de la muralla y la existencia de una habitación —la única conocida en esta área— en el extremo oriental. Esta habitación adosada a la muralla con un acceso situado al noroeste, presenta restos de una pavimentación que permiten suponer la existencia de un enlosado. En la zona sur de ésta, la vertiente rocosa muestra les restos de intensos trabajos de labra, que definen un conjunto de encajes, recortes y mechinales que nos permiten interpretar la existencia de los niveles superiores. No es objeto de este trabajo ofrecer una descripción excesivamente pormenorizada de las estructuras, que han sido objeto de publicaciones anteriores (Del Fresno Bernal, Socorregut Domènech, et al., 2023; Travé Allepuz et al., 2021, 2025).

2.2. Metodología y modelado tridimensional

El punto de partida para la generación de recursos digitales de investigación y difusión era la obtención de un gemelo digital del yacimiento al completo, es decir, de todo el recinto edificado sobre la colina y delimitado por la muralla. Para ello se han empleado dos métodos de captura de datos y digitalización combinados: el escaneo laser y la fotogrametría. Para el primero de ellos se utilizó un escáner Leica RTC360, y supone un sistema de digitalización activo capaz de capturar 2M de puntos por segundo (pps) con una precisión de entre 2 y 3mm. Nuestro criterio de base fue el de capturar lo

máximo posible de la geometría del monumento mediante este sistema, dada la elevada precisión que ofrece. De forma complementaria, la fotogrametría es un sistema de digitalización pasiva basado en la tecnología conocida como *Structure for Motion* (SFM), capaz de estimar y procesar una geometría o volumen tridimensional a partir de un conjunto de imágenes bidimensionales. De este modo, identificando puntos de referencia similares en imágenes contiguas se triangula la posición de las cámaras entre sí tejiendo una red nodal entre ellas que proporciona una nube de puntos que puede ser mallada y texturizada.

Ambos sistemas, por separado, constituyen en sí mismos métodos óptimos para la captura y elaboración de modelos tridimensionales. Sin embargo, la combinación de ambos es una práctica cada vez más extendida, especialmente en el ámbito de la digitalización de patrimonio cultural, puesto que maximiza los puntos fuertes de ambos y compensa sus debilidades potenciales. Así, mediante la captura activa —extremadamente precisa en la reconstrucción de las dimensiones y morfología del conjunto— se construye el conjunto de datos a partir de la cual realizar la malla del modelo y mediante la captura fotogramétrica se reconstruyen aquellos puntos no alcanzados mediante el láser (especialmente zonas más elevadas) y, sobre todo, aporta textura y características visuales fotorrealistas que permiten construir una representación fidedigna de la realidad.

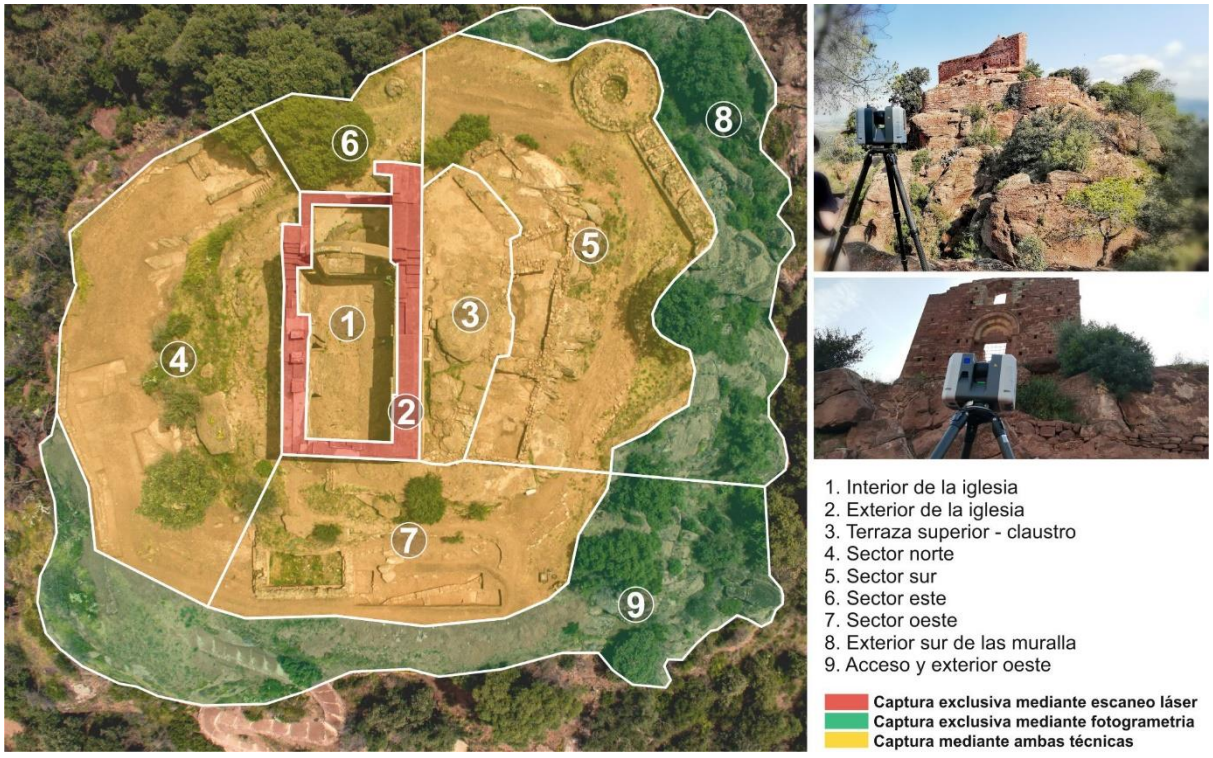

Figura 3. Sectorización y captura
Definición de nueve zonas de trabajo, siete de las cuales combinan ambas técnicas. El exterior de la iglesia constituye una zona de captura para el escaneo láser, pero su fotogrametría queda incluida en el resto de zonas.

Dadas las dimensiones del conjunto a documentar, que se extiende en una superficie aproximada de 4200m^2 se decidió sectorizar el conjunto en nueve áreas de captura de datos, de las cuales siete fueron objeto de una doble lectura mediante el escaneo láser y el barrido fotográfico y las dos restantes

sólo se documentaron mediante la fotogrametría, dada la imposibilidad de acceder a ellas con el escáner o la escasez de restos arqueológicos (**Figura 3. Sectorización y captura**). La sectorización tenía un objetivo doble: por un lado, asegurar una correcta captura del conjunto completo ya que los trabajos de documentación se llevaron a cabo durante varios días y, por otro, facilitar los trabajos de alineación del conjunto de datos al software de fotogrametría de manera fragmentada (Ot Padilla & Mauri Martí, 2024) (**Figura 4. Diagrama de procesado por sectores**). Ello posibilita aligerar la carga de los trabajos de procesado y actualizar las distintas partes del modelo a medida que avancen los trabajos de investigación, sin necesidad de afectar o procesar de nuevo todo el conjunto. Al final del proceso de captura de datos, contamos con cerca de 200 estacionamientos de escaneo láser y alrededor de 4000 imágenes del conjunto. La información fue procesada mediante la aplicación de software Reality Capture en su versión 1.4.3 (**Figura 5. Procesado de datos**).

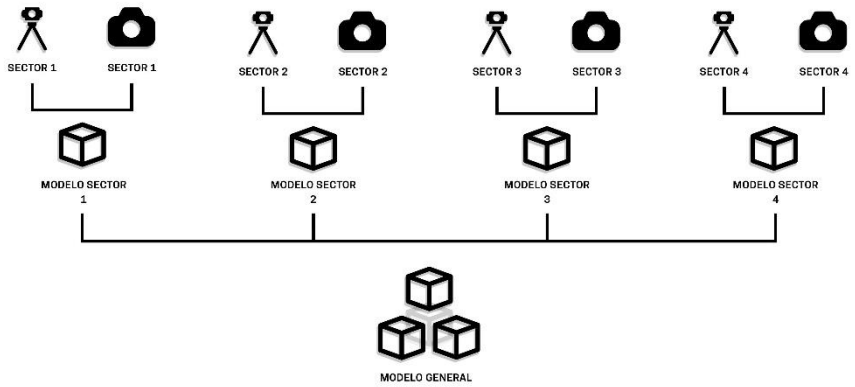

Figura 4. Diagrama de procesado por sectores
El diagrama muestra el método de captura (escaneo láser y fotogrametría) por sectores y el uso de los datos para la generación de modelos también sectoriales a partir de los cuales se genera el modelo general.

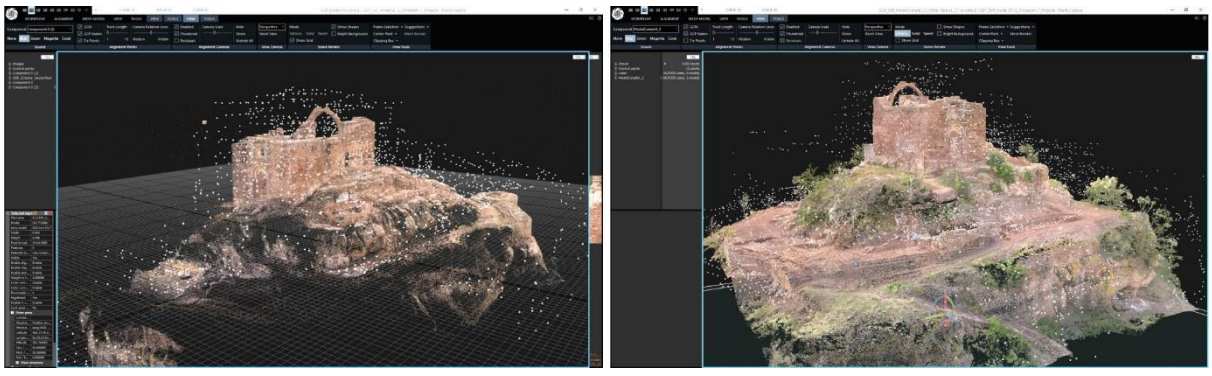

Figura 5. Procesado de datos
Construcción del modelo digital en la interfaz de uso de Reality Catpure 1.4.3 al principio del proceso (izquierda) y próximo a su finalización (derecha).

3. Resultados: un gemelo digital del monasterio de Sant Genís de Rocafort

En este apartado introducimos brevemente las características del gemelo digital de Sant Genís de Rocafort, actualmente finalizado y accesible, así como algunas de las estrategias de explotación y difusión empleadas; elementos que discutiremos a partir de la experiencia de trabajo.

3.1. El modelo digital

La combinación de los trabajos de escaneo láser y fotogrametría realizados en el yacimiento de Sant Genís de Rocafort nos han permitido obtener un modelo digital que incluye todo el recinto documentado en el interior de la muralla así como el perímetro conservado y estructura de la misma. El modelo inicial, a partir de una malla de 4000M de polígonos ($4 \cdot 10^9$) que empleó preferentemente los datos de escaneo láser, fue reducido hasta conseguir un modelo de alta definición posteriormente texturizado a partir de los datos fotogramétricos. Dada la exhaustividad de la captura de datos y la riqueza de la documentación, la reducción del modelo maestro a un modelo de alta definición que incluye sólo un 6.25 % del volumen de polígonos inicial, hace que la diferencia visual de los resultados sea prácticamente inexistente. El gemelo resultante es un modelo de alta resolución del monasterio y su entorno circundante formado por 250M de polígonos y 149 texturas de 8k (8912 x 8912 píxeles) (**Figura 6. Modelo digital**).

Figura 6. Modelo digital
Distintas vistas según la interfaz de visualización de NIRA

Un modelo de este tipo habría sido imposible de visualizar hasta no hace mucho, pero el lanzamiento hace cinco años de la aplicación NIRA (Keissami et al., 2019) nos ha permitido recientemente alojar el modelo y posibilitar su accesibilidad desde cualquier dispositivo a través del enlace https://cemartorellencs.nira.app/a/D_PuyINLTuGl5rEJ3G8Vhw/1. El modelo alojado, de 233,6M de triángulos y 10 Gpx de textura, permite visualizar en gran detalle las estructuras conocidas tras completar los trabajos de excavación arqueológica de 2024, que dan por finalizada una primera fase

de intervenciones. Contar con este tipo de recursos en la red, supone un hito muy importante en la difusión de estas creaciones que, hasta hace muy poco, habían quedado relegadas al uso profesional interno que pudieran hacer de ellas los distintos equipos de investigación para trabajos de análisis o estudio, ante la inexistencia de plataformas suficientemente potentes como para gestionar tales volúmenes de información.

La primera fase, pues, de este proyecto de generación de un recurso de realidad virtual inmersiva, queda concluida con la publicación del gemelo digital que hemos dado a conocer. El proyecto, sin embargo, continua no sólo en la creación de dicho recurso, sino también en la exploración de las distintas vías de desarrollo futuro para ulteriores tareas de investigación, difusión y aprendizaje.

3.2. Difusión y usos posteriores

En base al objetivo principal del proyecto, en los últimos meses se ha creado un recurso de realidad virtual inmersiva que reproduce la experiencia de visita a una exposición que acompaña el monumento con un conjunto nutrido de información acerca de sus características, los trabajos arqueológicos realizados y su historia. No en vano, la institución promotora del proyecto es un centro de estudios local —el Centre d'Estudis Martorellencs— con sede en el municipio que tiene entre sus funciones principales la preservación, difusión y puesta en valor del patrimonio cultural del lugar. Por todo ello, el interés en la creación de este recurso pretendía ir algo más allá de una simple experiencia visual, para ofrecer un recurso con valor educativo y pedagógico como herramienta de socialización de un conocimiento que, mediante otras formas de difusión, corre el riesgo de quedar algo restringido a una audiencia meramente académica.

La propuesta resultante constituye una experiencia inmersiva que contempla tres escenarios conectados entre ellos: (1) una sala de exposición, (2) el interior de la iglesia monástica y (3) el espacio exterior, donde se sitúan las dependencias monásticas. La pequeña sala de exposición inicial es el primer nivel de acceso, a través del cual se puede observar el gemelo digital de Sant Genís que preside el recinto a modo de maqueta, con algunos puntos de información y algunos paneles que sintetizan la historia del conjunto, acompañados por algunos objetos recuperados en los trabajos de excavación. Desde este primer espacio, se accede al segundo nivel que se sitúa en el interior de la iglesia a escala real, y a través de la cual el visitante puede desplazarse libremente hacia distintos puntos de información, preferentemente en formato auditivo. Desde el interior de la iglesia, a través de la puerta lateral de acceso al claustro, el visitante accede al tercer nivel de la experiencia y puede circular libremente a través de las ruinas del complejo monástico, especialmente en la vertiente sur de la terraza intermedia, en donde se hallaron el mayor número de restos. De igual modo, la experiencia se completa mediante el acceso a distintos puntos de información que explican y proporcionan detalles acerca de los elementos más relevantes de las distintas dependencias excavadas (**Figura 7. Exposición VR**).

En su formato actual, la experiencia puede visualizarse como un recurso de realidad virtual que denominamos *standalone*, ya que se ejecuta directamente utilizando el procesador interno de unas gafas de realidad virtual, en nuestro caso, unas Meta Quest 3. En un primer momento, se valoró la posibilidad de exportar la experiencia para PC (PCVR). Este formato carga y ejecuta la experiencia

desde el propio ordenador, y utiliza las gafas de RV como pantalla o visor. Las bondades de este sistema son realmente numerosas, ya que la potencia del PC no es comparable a la del pequeño hardware con el que cuentan los dispositivos de visualización VR. A pesar de todo, nuestra opción final se inclinó por empaquetar y exportar el resultado a *standalone* por la libertad y autonomía que este formato proporciona a la experiencia. Lo cierto es que, dada la capacidad limitada del hardware, este sistema cuenta con algunas restricciones o limitaciones importantes que hay que tener en cuenta a la hora de generar el recurso inmersivo y que hemos tenido que considerar.

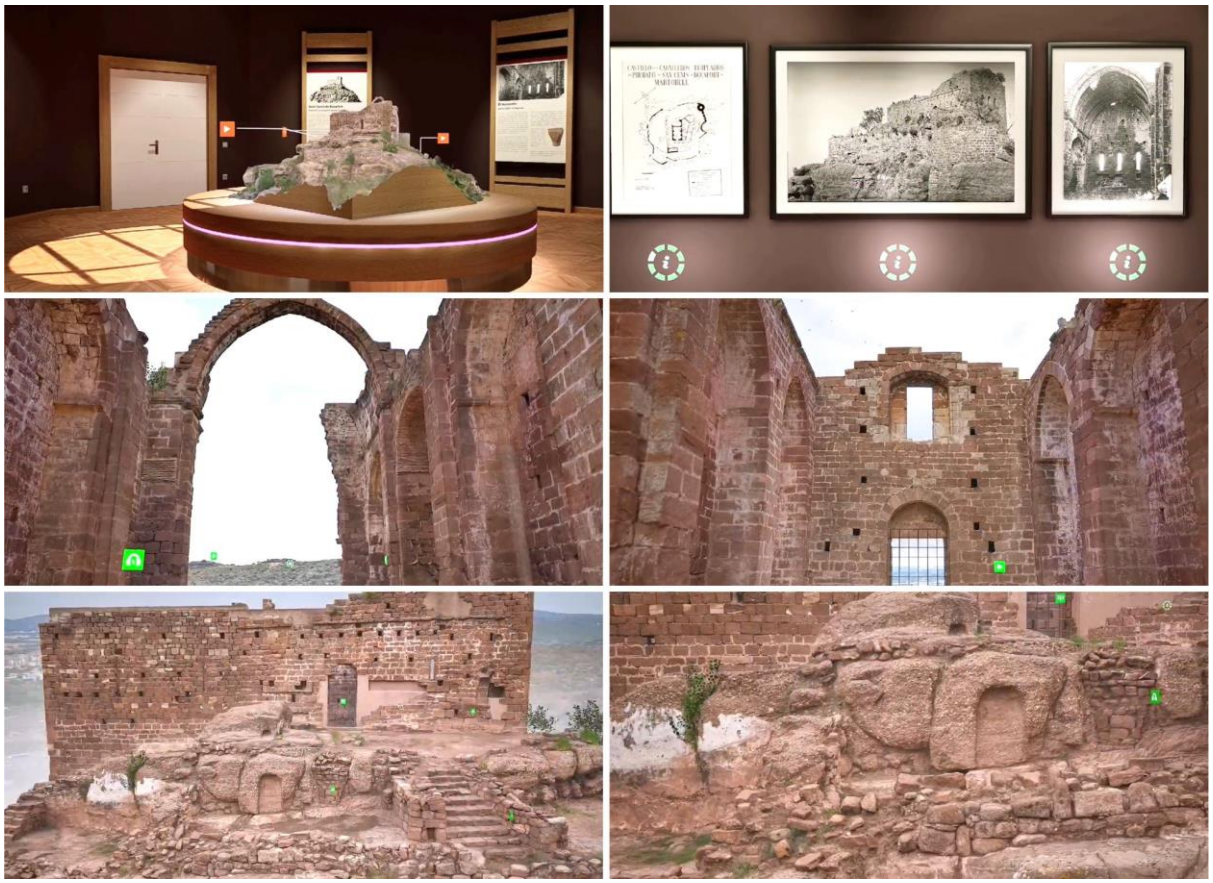

Figura 7. Exposición VR
Algunas imágenes relativas a los tres niveles inmersivos disponibles en la exposición virtual sobre Sant Genís creada por Virtual Past: Sala de exposición o primer nivel (arriba), interior de la iglesia o segundo nivel (centro) y dependencias monásticas al exterior de la fachada sur o tercer nivel de inmersión (debajo).

A nivel técnico, entre los aspectos a tener en cuenta a la hora de generar la experiencia inmersiva, la premisa era clara: debían optimizarse los modelos en pro de un funcionamiento eficiente del recurso. Para ello, se hizo necesario limitar el número de polígonos de la geometría a un número inferior al millón por nivel o escena creados. Del mismo modo, las texturas utilizadas no debían superar una resolución de 4k y había que fraccionar tanto el modelo como las escenas o niveles vinculados al mismo. De este modo, la información del modelo inicial correspondiente al exterior de la iglesia se omite, por ejemplo, en la visualización de la escena el interior del templo. Con todo esto, conseguimos reducir notablemente el número de polígonos y texturas (en más de un 75%) sin perjudicar excesivamente la calidad de la visualización final.

Otra de las prácticas recomendables que hemos llevado a cabo es la de fraccionar el propio modelo en diversas partes, que corresponden a diversos niveles, diferenciados por espacios, (**Figura 8. Fraccionado del modelo 3D**) a fin de optimizar su carga y visualización. Es más, esta práctica permite optimizar los recursos del dispositivo durante la misma ejecución de la experiencia, ya que, gracias a la tecnología de fragmentación, el propio motor de juego oculta los objetos o partes de la escena que no se están visualizando y mejora la velocidad de ejecución. El diseño de este recurso nos ha permitido garantizar una experiencia para todos los públicos que ha tenido gran acogida y cuyos materiales hemos puesto al alcance de todos (Travé Allepuz & Ot Padilla, 2025).

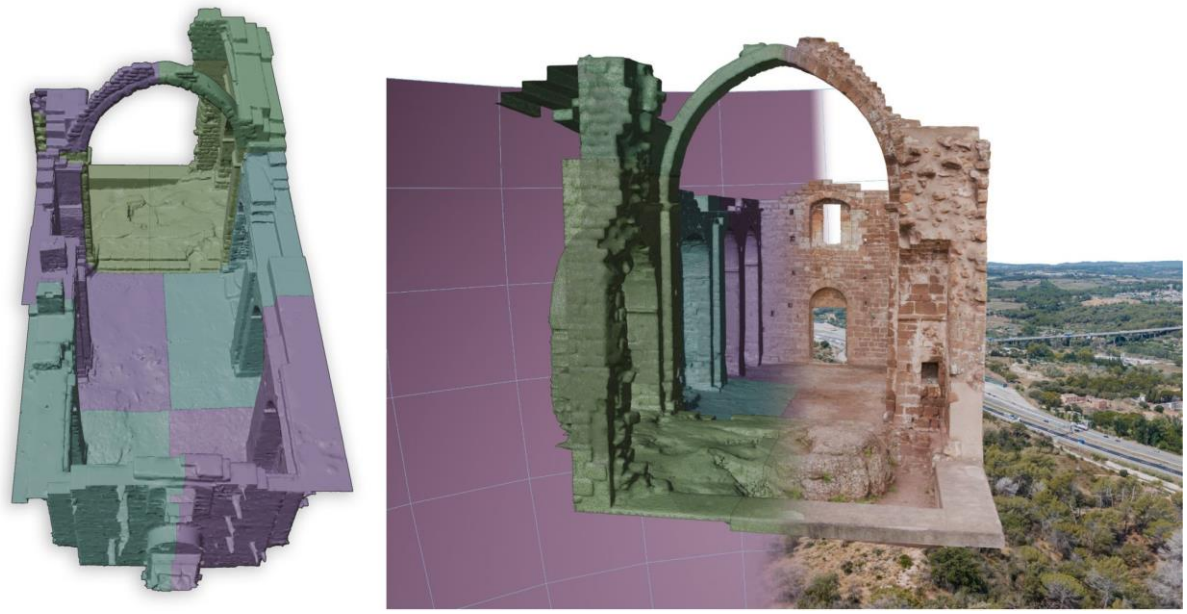

Figura 8. Fraccionado del modelo 3D
A fin de optimizar la carga y los recursos, los modelos virtuales de cada nivel se han fraccionado. En este caso, puede verse la geometría utilizada en el nivel interior de la iglesia, fraccionado en 10 partes (izquierda) y sus implicaciones en el diseño de escenarios VR (derecha).

4. Discusión: potencial y perspectivas de futuro

La experiencia de documentación tridimensional del yacimiento y la creación de un recurso de realidad virtual inmersiva ha supuesto un reto metodológico especialmente en la toma de decisiones que han acompañado todo el proceso. Sobre ello, nos parece adecuado discutir algunos puntos clave sobre la relevancia del proyecto en tres líneas distintas de actuación: el carácter propio de la documentación arqueológica, las posibilidades de ampliar significativamente el impacto de la investigación ante nuevos públicos y la posibilidad de hacer que los resultados obtenidos reviertan positivamente en la investigación de base.

4.1. Un elemento de valor patrimonial intrínseco: preservación y accesibilidad

La primera de estas cuestiones tiene que ver con la valoración que debe hacerse de este tipo de recursos desde una perspectiva puramente humanística o patrimonial: pensamos que la generación de gemelos digitales como el de Sant Genís de Rocafort constituyen elementos de valor patrimonial

intrínseco en tanto que garantizan la preservación y accesibilidad al monumento. Ya hemos mencionado anteriormente las vicisitudes históricas del edificio, cuyo ábside fue volado con dinamita a principios del siglo XX para su explotación ulterior como cantera. Obviamente, no esperamos que una agresión de este calado sobre el patrimonio se repita, pero en caso de que sucediera, contamos con una reproducción prácticamente perfecta en formato digital de la realidad conservada en 2024.

Quizás resulta inverosímil pensar en una destrucción deliberada del patrimonio, pero en una realidad como la actual, en la que el cambio climático ya ha alterado notablemente la frecuencia y virulencia de los fenómenos atmosféricos y naturales, no es descabellado pensar que, en los próximos años, la degradación por causas naturales de ciertos elementos patrimoniales pueda acelerarse. Por ello, parece recomendable desarrollar políticas de preservación digital de monumentos relevantes expuestos a la intemperie como estrategia útil para paliar las consecuencias de un cambio climático acuciante.

Por otro lado, al margen del potencial educativo del recurso, que también tendremos ocasión de comentar, tanto el gemelo digital como la experiencia virtual derivada, ofrecen una alternativa accesible a un segmento de población que en otras circunstancias tendría vetado el acceso al yacimiento por razones de movilidad. La localización del monasterio en lo alto de una colina no es un obstáculo insalvable para un conjunto amplio de la población, que puede acceder a él a través de un sendero de montaña, que goza de un mantenimiento razonable y una pendiente no excesivamente pronunciada, en un trayecto de algo menos de media hora. Sin embargo, queda limitado para la población de edad más avanzada o con dificultades físicas. Si pretendemos dar a conocer el patrimonio histórico y arqueológico de manera inclusiva y para todos los públicos, los recursos digitales creados permiten que toda la población pueda conocer el enclave con independencia de su edad o condición física.

4.2. La socialización del conocimiento: nuevos lenguajes y nuevos públicos

A lo largo de las últimas décadas, los avances tecnológicos en ámbitos muy diversos han transformado radicalmente nuestra sociedad hasta el punto de modificar algunos de nuestros comportamientos individuales y colectivos (Hoehe & Thibaut, 2020). El acceso a la tecnología o la amplísima difusión de las redes sociales han generado unos públicos proclives a la inmediatez y, desde la perspectiva humanística, las nuevas generaciones se han desvinculado en parte de la cultura escrita, el discurso profundo y el lenguaje natural en sus formas más complejas y reflexivas. No es objeto de este trabajo entrar en juicios de valor sobre estos procesos ni debatir acerca de su potencial reversibilidad. Sin embargo, como agentes de preservación, estudio y difusión del patrimonio, debemos ser capaces de utilizar los nuevos recursos a nuestro alcance para lograr de forma efectiva que el conocimiento que genera la investigación de base revierta en la sociedad mediante la creación de productos culturales de calidad.

El formato de visita virtual, en este sentido, se revela útil para nuestros fines, aunque todavía no parece constituir una herramienta plenamente consolidada en la difusión del patrimonio cultural, especialmente el de los bienes inmuebles. Al contrario, los modelos virtuales de elementos patrimoniales en su sentido más amplio —habitualmente restituidos a través de fotogrametría

exclusivamente— parecen abrirse paso de forma algo más decidida desde hace ya un tiempo (https://eureka3d.eu/). En cualquier caso, cabe señalar que los gemelos digitales no ofrecen interpretaciones históricas de lo que representan por sí mismos y requieren de un relato que los acompañe, que no siempre se presenta. En este contexto, el gemelo digital del monasterio de Sant Genís de Rocafort y la exposición que de él se deriva representan un caso paradigmático de cómo la tecnología puede ampliar el alcance del conocimiento, ofreciendo nuevas maneras de interactuar con los bienes culturales, permitiendo una aproximación más dinámica y envolvente y alcanzando nuevos públicos, especialmente entre la población más joven.

El uso de modelos tridimensionales y entornos digitales interactivos supone una evolución en los lenguajes de comunicación del patrimonio. Frente a las formas tradicionales de difusión, basadas en textos especializados, planos o visitas presenciales, la virtualización permite generar narrativas visuales que facilitan la comprensión del sitio por parte de un público más amplio. Esta capacidad de traducir el conocimiento a nuevos lenguajes tiene un impacto significativo en la socialización del conocimiento, pues convierte la experiencia en algo más accesible y atractivo para distintos sectores de la sociedad y en ningún caso supone la pérdida de públicos tradicionales, para los cuales se mantienen las estrategias anteriores. Uno de los logros, a nuestro juicio, de este tipo de recursos es que pueden sumarse a todo un conjunto de estrategias de difusión a las que complementan, pero no sustituyen. Además, este tipo de propuestas, permiten la incorporación de elementos multimedia de naturaleza diversa como locuciones, textos explicativos o animaciones que enriquecen el discurso interpretativo y refuerzan la transmisión del conocimiento.

4.3. Nuevos retos: la incorporación del modelo al registro arqueológico

Otro aspecto fundamental es la capacidad del gemelo digital para explorar distintas hipótesis de reconstrucción histórica y compartirlas de manera clara y visual. No hemos desarrollado todavía propuestas de restitución —ni que sea en forma de meros alzados volumétricos— dado que el registro arqueológico todavía está siendo objeto de revisión e investigación. En cualquier caso, el modelo digital es clave para la creación de dichas propuestas y su potencial es destacable. La existencia de dos pisos edificados sobre la terraza inferior y el acceso a al segundo piso desde la terraza intermedia es un dato sobre el que tenemos cierta seguridad a tenor del registro arqueológico, por lo que el paso a su modelado y restitución sobre el gemelo a fin de contrastar las distintas hipótesis de restitución que barajamos es inminente.

Experiencias en este sentido son ampliamente conocidas en el ámbito arqueológico, con especial aplicación a conjuntos edificados con un cierto carácter monumental (Bruno et al., 2010), pero también con perspectivas más amplias (Lucarelli, 2023). Uno de los retos pasa por combinar la propia restitución resultante con el proceso de documentación y toma de decisiones para dichas restituciones al propio registro arqueológico, generando un conjunto de metadatos y paradatos (Giovannini & Demetrescu, 2024) que todavía no está plenamente normalizado pero para el cual ya contamos con algunas propuestas previas y experiencias exitosas aplicadas a otros casos de estudio, como el desarrollo de una Matriz Harris Extendida (EHM o EM, por sus siglas en inglés) (Demetrescu, 2015;

Scopinaro et al., 2024). También en este sentido, la restitución de propuestas a través de la ilustración histórica, que es una técnica ampliamente extendida (Diéguez Uribeondo, 2019) y sobre la que ya hemos realizado algunos trabajos con anterioridad (Del Fresno Bernal, Ot Padilla, et al., 2023; Del Fresno Bernal, Travé Allepuz, et al., 2023) puede beneficiarse enormemente del gemelo digital en el caso de Sant Genís.

5. Conclusiones

Hemos querido dar a conocer a través de este trabajo una experiencia o estudio de caso relativo a la aplicación de herramientas de modelado tridimensional y realidad virtual inmersiva a la documentación, análisis y difusión del patrimonio edificado. La elaboración de un gemelo digital para el monasterio de Sant Genís de Rocafort i la creación de una exposición mediante realidad virtual inmersiva han supuesto un reto conceptual y metodológico que pasa por la toma de decisiones y la definición de protocolos de trabajo, y que hemos abordado a través de la realización de este proyecto. Uno de los principales retos es la necesidad de equilibrar rigor científico y divulgación, evitando caer en simplificaciones excesivas que puedan distorsionar la realidad histórica. El proceso de construcción del modelo digital de Sant Genís como parte de los trabajos de documentación y registro arqueológico y la construcción de un discurso visual basado en evidencias arqueológicas contrastadas garantiza el rigor científico a la vez que deviene comprensible y atractivo para el público general. En este sentido, la colaboración entre arqueólogos, diseñadores digitales y especialistas en comunicación resulta esencial para garantizar una representación fidedigna y eficaz del patrimonio.

El impacto de los nuevos lenguajes en la percepción social del patrimonio es un aspecto clave a considerar de cara a intervenciones futuras en otros yacimientos del territorio. La experiencia adquirida en Sant Genís de Rocafort ha dotado de herramientas para abordar la digitalización de otros yacimientos emblemáticos del territorio, como la iglesia de Santa Margarida, mencionada al inicio de este trabajo. En efecto, las posibilidades que ofrece la realidad virtual para reproducir entornos que permiten explorar un yacimiento arqueológico desde cualquier lugar y en cualquier momento contribuye a reforzar el vínculo entre la sociedad y su legado histórico, generando nuevas formas de participación y de implicación en su conservación. A medida que estas tecnologías sigan evolucionando, será necesario seguir reflexionando sobre su papel en la divulgación del conocimiento, sobre las oportunidades que ofrecen para redefinir la relación entre la arqueología y la sociedad y, especialmente, para hacer avanzar las disciplinas humanísticas a través del mundo digital.

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Simulacrum or Simulation[1] of Heritage: The Abade Case Study

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Abstract
Archaeology has undergone significant developments in recent times and is constantly adapting to the changing demands of modern society. As the contemporary world experiences constant and rapid change, the use of information technology resources is not merely a passive and complementary element of research, but an active and dynamic component in shaping the field. This article acknowledges the importance of this relationship and aims to explore the role of technology in enhancing archaeological research. Firstly, we will discuss the importance of computer simulation in archaeology as a novel way of "thinking the past" and as a training "metaphor site" for new professionals. Secondly, we argue that this new approach to archaeological science is not only a methodological advantage for predictive theses, but also an experimental platform for archaeological practice among sites. Thirdly, we bring up the potential of agent-based models and expert systems in the study of complex human and non-human systems, and in the construction of archaeological knowledge through an artificial inference engine. Finally, we provide an archaeological case study with the Abade Artificial Archaeological Site project (AAAS). In the following section, we provide a detailed account of this extensive project and demonstrate the potential applications and implications of virtual models and computer simulations in archaeology and beyond.

Keywords *Archaeological research, Information technology, Computer simulation, Agent-based models, Virtual models, Artificial Site*

1. Introduction: Computer Simulations on Archaeology

> *"With archaeological samples the randomness is often in doubt and the unavoidable lack of homogeneity due to phase sample distortion and compression has already been noted." (Clarke, 1978, p. 168)*

Computer simulation offers the unique advantage of creating "artificial worlds" where researchers can explore a vast range of scenarios and observe their outcomes. Archaeology, as an observational science, can sometimes focus too much on the technical aspects of its objects of study, leaving the complexities of human behavior to speculation. By incorporating computer simulation into archaeological practice, experimentation can become more dynamic and free researchers to adopt a more predictive approach, rather than solely relying on retrospective analysis. This allows for a more nuanced understanding of social practices and the factors that shape them over time. Computer simulation provides a third form of representation for human relationships, complementing the prevalent textual and mathematical equation-based methods in social studies. With simulations, researchers can test and evaluate hypotheses in a manner that can be repeated and refined by others. To clarify the approach, this paper first defines the role of agent-based models in archaeology, then presents the

application of this method in the Abade site case study, including the model's parameters, hypotheses tested, and the results obtained.

Numerous archaeological studies have successfully applied ABM, such as the Village Ecodynamics Project in the U.S. Southwest (Kohler et al., 2005), which simulated settlement and subsistence strategies over time. Internationally, tools like NetLogo (Wilensky, 1999) and Repast (North et al., 2006) have been employed to explore past mobility, resource sharing, and conflict emergence in ancient communities. However, it is important to note that there are limitations to this approach, as the accuracy of the results depends on the parameters and data used, which may or may not directly represent real-world variables. Computer simulations not only offer a new way to theorize and understand the real world, but they are also extensively used to train professionals. In non-linear environments, simulations provide countless possibilities for experimentation and learning, making them a unique tool for understanding complex systems. In the case of human relationships, the emergence of complex systems is the key to understanding how transformations occur in groups, as no single agent is solely responsible for these changes but rather a result of the interactions among multiple agents. As a metaphor for the real world, computer simulations can be explored in various ways by archaeology (Costa, 2020, 2022).

Social systems are intricate entities that embody complex and multifaceted human behaviors. Consequently, the archaeological investigation of social practices is an ongoing endeavor that entails the continual construction and deconstruction of knowledge acquired from historical and scientific sources. As posited by Gilbert (2004), unlike the relatively predictable linear systems that pervade the physical world, human relations are largely unpredictable and subject to diverse outcomes. Thus, human societies are complex systems, and their understanding cannot be achieved solely through the study of their individual components, as is characteristic of the "hard" sciences such as physics, chemistry, or biology. Rather, the behavior of a society is said to "emerge" from the actions of its constituent units.

Moreover, human societies are dynamic entities that undergo constant transformation, making their study an ever-evolving process. Gilbert and Troitzsch (1999) have argued that the use of simulations in social sciences is a relatively new field, and despite being in use since the 1960s, the application of computers to generate simulations only became popular in the 1990s. Based on complexity theory, computer simulations are a type of virtual modeling that simplifies the study of complex phenomena. Like statistical models, computer simulations have one input and one output data system; however, they differ in their ability to incorporate "nearly" infinite variables. Therefore, the main characteristic of computer simulations is their predictive power, which can be used in combination with expert systems or independently.

It has been more than forty years since archaeologists began showing a keen interest in the use of computer simulations (Doran, 1970, 1999, 2005; Hales and Doran, 2018). However, unlike other social sciences, which have made significant progress in this area since the 1960s, the use of simulations in archaeology has remained largely stagnant in the 1980s, with only a

few notable reborn in the 1990s and 2001 after all expansion (Lake, 2014). Although past critiques questioned whether human complexity could be captured in models, more recent research has shown that simulations can meaningfully represent household-level decisions, long-term demographic change, and landscape interaction (Kohler and Van der Leeuw, 2007).

However, this argument fails to acknowledge the nature of computer simulations and their great capacity for abstraction. Computer simulations are not simply mathematical models but are virtual models that can account for a wide range of variables and can be used to make predictions. Therefore, the potential for computer simulations to contribute to archaeological research should not be underestimated. While mathematical models rely on equations to represent systems, virtual models in ABM simulate the behavior of agents over time, offering dynamic interaction and visual feedback. In this context, simulations serve as both models and experiments, bridging empirical data and theoretical insight. Unlike earlier publications, this paper integrates empirical ABM application with virtual reconstruction and discusses the methodological evolution of the project from 2012 to its current digital form.

2. A new way of doing Archaeological Science?

The use of computer simulation in archaeology has been primarily limited to interpretive aspects and methodological fields, and there is a need to bring the power of formulated abstractions to the theoretical field of experimentation. By doing so, archaeology can construct a third means of scientific knowledge that goes beyond the traditional inductive and deductive approaches. This will allow for a more comprehensive understanding of complex human behaviors and relationships and provide new insights and perspectives in archaeological research. But to do this, is it also possible to adopt a dialectical approach? Dialectics involves the study of contradictions and how they interact and transform over time. In the context of archaeology and computer simulations, dialectics could be used to examine the tensions between different theoretical approaches and to explore how these approaches can be synthesized or transcended by simulations. Additionally, dialectics could be used to analyze the interaction between the simulated world and the real world, and how this interaction shapes our understanding of the past.

The current use of computer simulations in archaeology is becoming increasingly feasible as various obstacles previously identified as responsible for its disqualification are being overcome. Firstly, hardware processing capacity assisted by the development of powerful software has increased exponentially compared to previous decades, today from Quantum Computers to AIs. Secondly, the pioneering and vanguard characteristics of many simulations in social sciences are today recognized as demonstrating efficacy and legitimacy. And thirdly, many modern theories provide theoretical and explanatory support to computer simulations, thus allowing for their broader acceptance in the scientific community. On the other hand, complexity theory is the study of emergent properties that arise from interactions among agents. According to this theory, the real world is not composed of isolated segments but of

relationships that emerge among different elements. These relationships are independent of each other but are simultaneously influential. It is thus incorrect to claim that a systematic study of one part can reveal the whole, because only the conjunction of its parts can be representative of the relationships that occur in the Whole.

In archaeology complexity theory has been presented also since the 1960s in the form of systems theory, however even the actual discourse of multivariate causality is only part of its epistemology. Complexity theory evokes unbalanced systems where the emergent properties are the means to grasp the whole rather than the sum of its parts; complexity theory challenges the reductionist approach that seeks to understand a system by analyzing its individual components in isolation. Instead, complexity theory emphasizes the interconnectedness of these components and how they interact to create emergent properties that are not present in any individual component alone. In archaeology, this means that studying a single artifact or site in isolation may not reveal the full picture of the society or culture it belongs to. Instead, it is necessary to consider the interactions and relationships between different artifacts and sites to gain a more comprehensive understanding of the society or culture. Complexity theory provides a framework for exploring these relationships and emergent properties in a systematic and holistic manner.

An applicable concept from complexity theory in archaeology is the "Power Law," which is also widely used in physics. The Power Law describes how the distribution of a phenomenon can occur through the accumulation of a given element by agents that already have a large quantity of it. A classic example of this is the "rich-get-richer" process in the economy. The Power Law has potential applications in archaeology, particularly in understanding the accumulation and distribution of material culture and the emergence of social hierarchies in past societies. By applying the Power Law, archaeologists can gain insights into the complex relationships between agents and the emergent properties that arise from those relationships, in a questionable and unilinear Evolution of the algorithm besides its skews.

3. ABM’s Archaeology and “Black Box” Systems

Agent-based models, or ABMs, are one of the most widely used products of complexity theory in the social sciences. Several archaeological projects have demonstrated the usefulness of ABMs in creating ‘virtual worlds’, including simulations of urban growth, social conflict, and settlement distribution (Doran 1999; Lake 2014). These models allow researchers to test a wide variety of theories that differ from normative approaches like historical-culturalism, hypothetic-deductive models of processualism, or multiple narratives of pos-processualism. They also allow for the incorporation of ecological, gender, class, and other perspective models. Agent-based models work through successive stages of action, where the interactions among agents occur according to primary information generating changes in their environment, which in turn are fed back into the system with new information. Appearing as an

endless loop, this process brings out the relationship between proprieties and establishes the dynamic of action in a complex system.

Agent-based models operate through a series of stages in which agents interact with each other based on primary information. These interactions generate changes in the environment, which are then fed back into the system with new information. This feedback loop creates a dynamic relationship between properties and establishes the action dynamics in a complex system. At each stage, agents make decisions based on their internal rules, goals, and the information they receive from other agents or their environment. These decisions can lead to emergent behaviors—such as spatial clustering or conflict—that mirror human patterns observed archaeologically, thereby offering insights into past social dynamics. By simulating the behavior of a complex system, ABMs provide a powerful tool for studying the dynamics of social, economic, and ecological systems, human or not. The broader relevance of ABM beyond archaeology is supported by its successful application in fields such as urban planning, epidemiology, and economics (Epstein, 2006), emphasizing its flexibility in modeling complex adaptive system.

Multiple-agent models, a variant of ABMs, have been identified as the most effective means of constructing social simulations on computers. These models are software collections that interact within an artificial environment, where each agent follows predetermined parameters of action based on input data, and variations can be observed. Multiple-agent models can be used to project hypothetical situations from factual data or evaluate actual situations by comparing results. However, these models, like all simulation models, are subject to two major complications. Firstly, the random character of simulations means that initial parameters will always affect predicted variables. Secondly, there is a tendency towards repetition, where similar results do not always mean identical processes. Despite these limitations, multiple-agent models are a valuable tool for exploring and understanding complex social systems. By simulating the behavior of multiple agents in an artificial environment, researchers can gain insights into the ways in which individual behaviors combine to shape larger patterns and trends.

Starting with a simpler model and gradually introducing variables to observe reactions is advised. The model can be thought of as a construction filled with objects, which can be categorized into dynamic and static objects. There is a hierarchy between these objects, and each one has its own attributes that function like variables in a mathematical equation. The next step is to establish an environment where the objects can interact in a spatial or relational form. Finally, this establishes the dynamics of the model, first between the objects and the environment, and then among the objects themselves. Each object creates a set of rules of action and reaction, which contribute to the overall dynamics of the model. By following these guidelines, researchers can develop more effective and accurate agent-based models. Because of that, it is also recommended to develop a strong research design before executing the project.

“Black Box” or expert systems in archaeology are typically composed of two main components: a knowledge base and an inference engine (Gardin, 1988). The knowledge base is where all the relevant information and rules about a particular subject are stored and organized. This includes both factual knowledge, which is the observed data related to a given topic, collected with scientific precision and technical intent, as well as operational knowledge, which is constructed through inference rules. Factual knowledge is typically derived from archaeological data, such as artifacts, structures, and environmental data, which are collected through fieldwork, laboratory analysis, and other scientific methods. This data is then organized and stored in a knowledge base, where it can be accessed and used to generate new insights and hypotheses. Operational knowledge, on the other hand, is constructed through inference rules, which are logical statements that describe how different pieces of information are related to each other. Some inference rules may be specific to the object of study, while others may have a broader application.

The inference engine is responsible for using the knowledge base to generate and reproduce intelligent constructions about domains. It does this by applying the inference rules to the available data in the knowledge base and using them to generate new insights and hypotheses. Overall, expert systems provide a powerful tool for archaeologists to organize and analyze large amounts of data, and to generate new insights and hypotheses based on that data. By combining factual and operational knowledge in a structured and organized way, expert systems can help archaeologists make sense of complex social and environmental systems in the past and gain a deeper understanding of human history and culture. Computer simulations in archaeology can contribute to both factual and operational knowledge.

In the case of factual knowledge, computer simulations can help in the collection of data related to a site or event. For example, by creating a simulation of a past civilization, archaeologists can gather data on the structures, artifacts, and environment of that civilization. This data can then be analyzed and compared with other data collected from different sources to draw conclusions about the past. In the case of operational knowledge, computer simulations can help in the development of new inference rules and scientific constructs. For example, by creating a simulation of a past event or process, archaeologists can test different hypotheses and scenarios to see how they play out. This can help them to identify patterns and relationships that may not be immediately apparent from other sources of data. The results of these simulations can then be used to develop new theories and interpretations about the past.

Computer simulations in archaeology can serve as an expert system of knowledge that can be applied in various situations to help researchers solve problems or explore new possibilities without having to redo the research. This is because computer simulations allow for the application of variables to archaeological sites or facts, which can be validated and debugged through the simulations. The simulations can also serve as a knowledge base for both factual and operational knowledge, allowing for the creation of new scientific constructs and the exercise of new actions of inference.

4. The Abade Artificial Archaeological Site Project (AAASP)

Today, in the Pireneus Mountains, approximately 125 Km from Brasília, in the municipality of Pirenópolis, the remnants of the mining village serve as the subject of this study. The Abade is a significant historical archaeological site in the state of Goiás, Brazil, consisting of the remains of a goldmine from the late nineteenth century. The mine operated from 1880 to 1887, and its village was destroyed in an attack by local villagers. This was due to water pollution as well as political and economic disagreements. An ongoing project since 2005 has been the creation of a virtual model of the historical archaeological site Lavras do Abade (Costa, 2024).

Figure 1. Lavras do Abade in 1884

Advanced planning of field activities is a crucial aspect of any archaeological research, but the objective here goes beyond the current stage of this investigation. We aim to recreate the object of study within a controlled environment that is open to interactions with the researcher. The virtual model of the Abade site was created using a combination of digital, environmental, geographic, and historical data. This data was obtained from a variety of sources, including historical documents and photographs from both public and private archives detailing the events of Abade. Adhering to Prince and Deetz's methodological principles, historical photographs of the site from 1883 were utilized to locate and identify the remnants of structures at the archaeological site. However, the outcome was not satisfactory due to excessive vegetation that hindered the precise overlay of images on the site. This was exacerbated by the distortion present in the old pictures, as well as the condition of the landscape, which was entirely devastated at that time. Significant progress was achieved by combining the data obtained from the digitalization of the remaining structures to construct a computer model of the site. The digitalization process was initiated in 2005, where a 3D scanner was employed to produce a virtual replica of the vestiges above the soil. In the month of June that same year, a week-long laser measurement scanning of building structures was conducted at the Abade archaeological site.

To conduct the scanning, a Trimble/Mensi 3D GS200 laser scanner was utilized. This scanner has a resolution of 32μrad, which means that it can capture a point up to 03 mm away at up to 100m with a precision of 1.5mm @ 50m. The capture rate of the scanner reaches 5000 pts/second and employs a Class 3R (IEC 60825-1) and Class 2 (21 CFR §1041.10) laser. The device was geo-referenced using a Z-Max receptor of dual frequency with a precision of 05 mm + 0.5 ppm and a single frequency Promark2 receiver with a precision of 05 mm + 01 ppm. The 3D scanner is a remarkable device that collects information from any object in three dimensions by using a laser to measure the distance between the object and the scanner. The software accompanying the scanner can add texture and color to the shape of the captured object with the help of digital photography. To digitize the structures in the Abade site, the equipment was placed in the immediate surrounding areas of the structures. At each capture site, the X, Y, and Z coordinates of more than 20 million dots, each with a diameter of less than 1.5mm, were collected. Additionally, each location of the scanner was geo-referenced for the creation of a topographic surface. This process resulted in the generation of a point cloud file that produced an exact replica and scale of the scanned structures within the site.

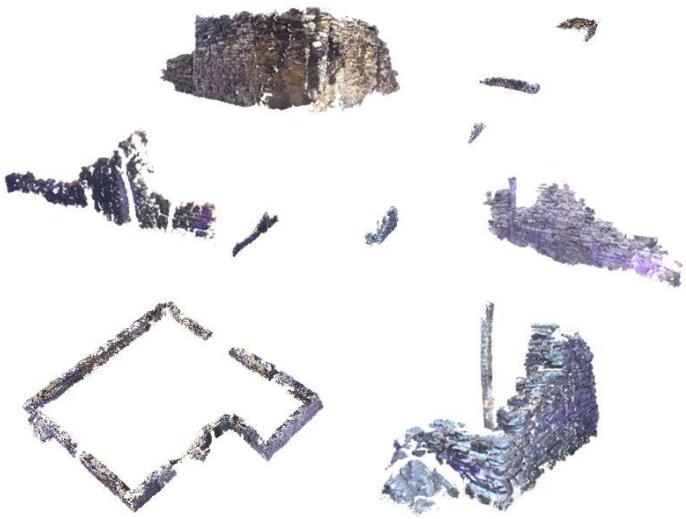

Figure 2. Point cloud of the site (2005)

Following the scanning process, a consolidation of the point cloud was conducted to verify the accuracy of the survey. In the second stage of the construction of the mathematical model of the site, the point cloud file generated from the scanning stage was imported into a software called AutoCAD Civil 3D. The software was used to create a 3D mathematical model of the site, using the point cloud file as a reference. The model was then used to create a virtual environment that could be explored and interacted with. The virtual environment was intended to simulate the real environment of the site as accurately as possible and was populated with detailed 3D models of the structures and objects present in the site, as well as natural elements such as vegetation and terrain. The virtual environment allowed for the study of the site in a controlled environment, and for the simulation of various scenarios and hypotheses related to the history of the site. A more comprehensive virtual model of the site was created using

Google SketchUp Pro Version 6.4.112 software. This involved constructing a 3D model of the entire village, incorporating both the remaining building structures from the site and those present in photographic documents of the village, which were processed in Adobe Photoshop CS8 software to correct for perspective, lens distortion, and adjust the resolution and scale of the images. One of the main goals of this photometric work was to extract three-dimensional measurements for the creation of a two-dimensional computer model.

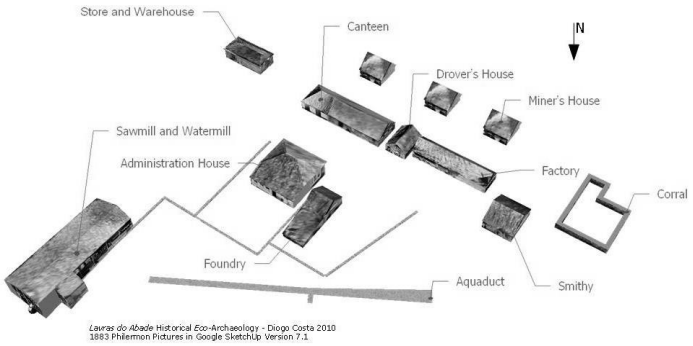

Figure 3. Virtual model of the site (2010)

The use of the virtual model for planning the field investigations allowed for a more efficient and targeted approach to the excavation process. By identifying areas of interest based on the virtual sketches and analysis of the sedimentary rock matrix, the excavation process could focus on those areas and potentially yield more significant findings. This approach not only saves time and resources, but also increases the likelihood of discovering artifacts and structures that could provide valuable insights into the history of the site. Furthermore, the virtual model allowed for the creation of animations that provide a visual representation of the site and how it may have looked and functioned in the past. This can aid in public outreach and education efforts, as well as in communicating research findings to other professionals in the field. The animations can also be used to test hypotheses about the site and its occupants, and to explore different scenarios or interpretations of the available data.

Overall, the creation of a virtual model can greatly enhance the archaeological investigation process and help to unlock the secrets of the past. The use of laser level and laser tape measure during field investigations helped to collect accurate measurements of the archaeological layers and levels at the site. The laser level Inventek V21384 was used to generate two vertical planes and one horizontal leveling plane, which enabled the measurement of height and depth of the archaeological layers. The Stanley FatMax TLM100 77-910 laser tape measure was used to record the measurements with an accuracy of ± 6mm up to 30m. The use of these instruments helped to improve the accuracy of the virtual model of the site, by providing feedback on the actual measurements of the site. In some cases, special glasses were used to view lasers under natural lighting conditions. This approach highlights the importance of using a variety of technologies and instruments to collect accurate data during field investigations and feedback to the constructed virtual model.

The field collected data during the posterior campaigns of 2007 and 2008 was included in the electronic model of the virtualization of the sub-superficial archaeological package present in the site. In 2009 a soil collection and chemical analyses of soil from around the site was planned, conducted, and tested in the virtual model. These tests were very positives about the possibilities of application of virtual models in archeological research, as well functioning as a working space for trial and error for both theoretical perspectives and practical actions in archaeological sites. The model also served as a virtual repository of all research conducted, and has therefore been an effective way to store, use and review the collected data and results. Moreover, the virtual model has allowed for the creation of new research questions, the exploration of alternative scenarios, and the development of new hypotheses. It has also facilitated communication and collaboration among researchers, as well as with the public, by providing a visual and interactive representation of the site and the research conducted. The virtual model of Abade has thus been a valuable tool in archaeological research, contributing to the advancement of knowledge about the site and the past societies that inhabited it.

The intersection between field work and the planning office forms the fundamental marks of archaeological research. The virtual model of Abade besides illustrating and animating work of exploring the archaeological site, also served to record the full suite of research activities and data collection activities. As a digital reproduction of the site an important and new stage study in the preservation of archaeological patrimony was reached: the test of research. Hitherto relegated to a later stage of data collection in archaeology, laboratory practice here also may be understood as experimentation and not only identification, analysis, and interpretation of the vestiges, and therefore attains another status.

The virtual model of Abade allowed for a more integrated approach to archaeological research, where the fieldwork and planning stages were closely linked. This integration allowed for a more efficient use of resources and a better understanding of the site (as a whole). Additionally, the virtual model provided a space for experimentation and testing, which is an important aspect of archaeological research that is often overlooked. The digital reproduction of the site allowed for a more thorough examination of the collected data and a more comprehensive understanding of the archaeological patrimony.

> *“The laboratory of an archaeological site is now also a theoretical field, where the praxis is established by the junction between the real and the virtual. In this way, the data collected at a site are not only the result of an archaeological investigation, but also the basis for the creation of a theory from the data itself. A step forward will be realized with the integration of existing data with specific software and computer simulations and comparing the obtained results with new archaeological investigations proposed for the site, feeding back in a continuous manner to form a truly expert system of knowledge about the Abade archaeological site.” (Costa, 2012)*

The integration of existing data with specific software and computer simulations can indeed help in advancing archaeological research. This approach allows for the testing of various hypotheses and scenarios, which can aid in developing a deeper understanding of the site and its history. Additionally, the use of expert systems and artificial intelligence can help in identifying patterns and trends that may not be immediately apparent through traditional

analysis methods. Overall, the use of technology in archaeological research has the potential to revolutionize the field and greatly enhance our understanding of the past. The Abade model also functions as a didactic tool, aligning with recent pedagogical strategies that incorporate simulations in heritage education (Champion, 2011).

5. The Virtual Life's of AAA Site

In 2012, I started another phase of research in the project, which was more practical in nature. This study involved the selection, implementation, testing, and application of various types of software for use in creating computer simulations for archaeology. The research was conducted using a systematic sequence of phases, with each computer program evaluated in different ways and possibilities. The project comprised four research phases, each with its own distinct execution and outcomes, as well as a partial assessment of each stage. The phases consisted of: Phase 1 - Researching simulation software on the internet; Phase 2 - Operating simulation software; Phase 3 - Testing simulation models of the software; and Phase 4 - Creating and testing simulation models for archaeology.

The research of simulation software on the internet was the first step in the project execution. By reading specialized literature beforehand, the decision was made to "scour" as many simulations' software related to human and biological sciences as possible. Hence, software dedicated to computational simulation in exact sciences was ignored as their profile did not correspond to what was sought by this research project. During this stage, various websites related to the topic were visited, and participation in some discussion forums about the subject, as well as email contact with certain responsible parties for the programs, was made. It is worth noting that a significant portion of the universe explored on the topic is in the English language, which is not only a global reference in scientific publication but also exhaustively used in the computing environment.

The main objective here was to establish the level of production in the area, as most of the software is a product of academic research, with a few commercial ones. Therefore, despite most academic software being free to use, their specificity ends up restricting their applicability. On the other hand, commercial software is the most adaptable to different requirements and resilient in the long term. Most of the software was obtained for free with their licenses available in the form of open-source or free software. Some were only available as a trial or limited in their time or applicability. Unfortunately, most free software is somehow outdated, which was one of the primary factors observed during their installation, and some were completely absent after reviewing this text.

The selection of software to be installed occurred primarily based on availability and compatibility, with an attempt to cover various types of programs, including both paid and free ones, as well as different operating systems such as DOS, Windows, and Linux, and various programming languages such as Visual Works, C++, Python, Java, Unix, among others. The

conclusion of this first phase was the selection of 31[2] simulation software programs, which were found on various sites and discussion forums. Often, the direction of one program was given by its predecessor since the field is still in development, and study groups on the subject are still limited and not easily accessible. This initial phase of the project took approximately three months of research, during which, in addition to acquiring the software, it was also necessary to gain a basic understanding of each one.

The implementation and testing of the software acquired in the first phase of the research was conducted next. In this phase, the installation and execution of each of the 31 programs were tested, using a dedicated computer for this purpose. The computer used for the second and third testing phases was a Gateway MX3215 Notebook, equipped with an Intel® Celeron® M Processor 360 with 1MB L2 Cache, clocked at 1.4 GHz with a 400 MHz FSB. It had a memory of 500 MB DDR2 (2 x 256 MB) SODIMM (PC4300), and a 60 GB HDD (4200 RPM). The computer operated on the Windows XP environment. This phase of the project aimed to identify which software offered a more user-friendly and easily diffusible environment, as well as the limitations and potentialities of each program. Another fundamental point of this phase was to select which programs would be the best application in conducting specific simulations in archaeology.

Not all software were able to be properly installed. In some cases, limitations of the equipment, as well as incompatibility or software errors were constant issues. Additionally, some software, despite being installed without any issues, did not operate correctly or completely, making it impossible to proceed with further testing in subsequent phases. This second phase of the project took approximately six months of research, being responsible for the operability, acquisition, and installation of the programs. Of the 31 installed software, only 18 were selected for the third phase of testing. A new phase was established and aimed to evaluate the applicability of simulation models present in the software. To do so, tests were carried out with these models in different simulation options, to evaluate processing time, parameter variation and results achieved. The main observation of this phase was that not all simulation software models have the same simulation characteristics. Some programs focus more on driving physical reactions between agents, while others allow for a wider range of interactions and nuances.

It is therefore noteworthy that each tested software has its specificities and qualities, thus requiring a subsequent evaluation stage. Therefore, some software did not respond satisfactorily to the proposal of this research, especially regarding its applicability in a popular environment such as Windows and were thus disregarded for the next phase. This third phase corresponded to another six months of the research, and out of the models present in the 18 tested software, only 09 were selected for the subsequent phase. Of the 18 software programs tested previously, only 9 were selected as the best to be used in archaeological simulations. The reason for this selection was mainly because these software programs presented models suitable for the inclusion of archaeological data, as well as their easy manipulation and wide

range of applications. The next phase involves applying the same model across the remaining software to determine which responses are similar or not, establishing the limits and applicability of the results. The aim of this phase is to create specific simulations for archaeology, so that it will be possible to test the different programs that best fit the project's proposal.

However, due to the revision of this text for publication, the websites of the remaining 9 software's were revisited, and unlike what was found at the beginning of this research in 2012, ten years later, significant changes occurred in all platforms. Of this 9 selected software's, 3 were completely discontinued without a specific date or information, 3 are stalled and haven't received upgrades since 2006, 2009, and 2015 respectively, and the remaining three software packages are up to date with updates in 2020. In this specific case of the remaining 03 programs in the analysis, 01 was for commercial use and the other 02 were for educational use.

In the end, it was determined that the ABM was probably the best model for providing feedback to the Abade Site. Agent-based modeling is a relatively new method when compared to discrete event modeling and system dynamics. As a middle range theory for archaeology, the ABM offers a multimethod platform, in which the entire model or a part of it can be composed of one method, while another part can use a different method. This flexibility allows researchers to better capture the complex interactions that occur within a system, resulting in more accurate and nuanced analyses. In archaeology, a middle-range theory is an approach that seeks to link the material remains of the past with the social and cultural practices that produced them. As suggested by Binford (1981), middle-range theory in archaeology serves to bridge the gap between empirical observation and abstract explanation. ABMs, by simulating processes linking material patterns to human behavior, offer a robust platform for operationalizing middle-range frameworks (Premo, 2006).

It is a bridge between specific archaeological data and broader anthropological or historical models. Middle-range theories aim to explain the relationships between artifacts, archaeological sites, and the cultural systems that produced them, without making sweeping generalizations about the past. They are grounded in empirical evidence and are often formulated through ethnographic or experimental research. ABMs allow for the representation of complex interactions between agents and their environment, making them well-suited for modeling social dynamics and human behavior in the past. By representing the actions and decisions of agents within a simulated environment, researchers can test different hypotheses and scenarios related to middle range theories in archaeology. Model validation remains a challenge in archaeological simulation. As Railsback and Grimm (2019) note, transparency in design and iterative testing against known archaeological cases are essential to reduce bias and increase model robustness. A summary of the model architecture, input parameters, and key emergent outcomes is provided in this paper. The full interactive simulation can be accessed online at: https://www.anylogic.com/resources/articles/the-abade-artificial-archaeological-site-project/.

6. Last Considerations: Simulacrum or Simulation in Archaeology?

Agent-based models are considered revolutionary in the social sciences for several reasons. Firstly, they do not require the old rules of equilibrium, normality, and linearity that traditional modeling approaches often rely on. Instead, they allow for the emergence of complex, nonlinear, and unpredictable behavior that is more in line with the realities of social systems. Secondly, agent-based models demonstrate the phenomenon of emergence, which means that complex patterns and behaviors can emerge from the interactions of individual agents, even though these patterns may not be predictable from the behavior of individual agents alone. This is a key feature of social systems, which are often characterized by emergent phenomena. Finally, agent-based models provide a more natural representation of social systems than traditional mathematical approaches because they simulate the actions of individual agents within the system. This allows for a more nuanced understanding of social processes, including the role of individual agency and the ways in which different factors interact with each other.

Computer simulation has three main uses in archaeology. Firstly, it can generate "artificial" data that can be used to compare or supplement actual hard data, which is always incomplete and may not fully capture the complexity of social phenomena. Secondly, computer simulations can complement analytical models, which may provide individual answers but do not work together effectively. By simulating social processes, researchers can gain a more comprehensive understanding of how different factors interact with each other to shape social outcomes. Finally, computer simulations can be used to generate analytical models when they do not exist. This is particularly useful in cases where social phenomena are too complex to be understood through traditional analytical approaches or where the available data is limited. Through computer simulation, researchers can explore different scenarios and test hypotheses in a controlled environment, allowing for a more nuanced understanding of social processes.

While computer simulations in archaeology can be used to generate results, their primary use is often to debug the analytical process. In other words, simulations can be used to test and refine analytical models by comparing the simulated data with actual archaeological data. In this sense, computer simulations can be seen as autonomous systems of knowledge or a “Black Box” that provide a tool for archaeologists to construct artificial support for the process of data interpretation. By using simulations, archaeologists can test different hypotheses, evaluate the impact of different factors, and explore alternative scenarios that might not be possible through traditional archaeological methods alone. Overall, computer simulations offer a valuable tool for archaeologists to refine their analytical processes and gain a deeper understanding of complex social and environmental systems in the past. While simulations are not a replacement for traditional archaeological methods, they can complement and enhance our understanding of archaeological data in important ways, without merely being a simulacrum heritage.

Following Baudrillard (1994), *simulacra* refer to representations that have lost their connection to an original referent, whereas simulation, as applied here, maintains a functional relationship with empirical data — not to replace reality, but to test its internal logic. Despite their significant potential, agent-based models in archaeology still face important limitations, such as challenges in model validation due to incomplete datasets, the inherent subjectivity in rule-setting, and issues related to the obsolescence of simulation software. Future research should aim to improve transparency in model design, foster interdisciplinary training, and support the development of open-access simulation platforms tailored to archaeological practice. Additionally, expanding comparative datasets and encouraging community-driven modeling efforts can enhance the reliability and interpretive value of ABMs — ensuring they serve as rigorous analytical tools rather than mere *simulacra*.

Although as mentioned earlier in this text, computer simulation was not widely accepted in archaeology during its early development (Doran & Palmer, 1995; Gilbert & Troitzsch, 1999; Epstein, 2006; Lake, 2014), this resistance was largely due to disciplinary conservatism and skepticism toward computational approaches that were perceived as too experimental or insufficiently validated. In recent years, however, the growing adoption of agent-based models and other simulation techniques has led to increasing recognition of their value for exploring complex social phenomena, particularly in archaeology (Cegielski & Rogers, 2016; Carney & Davies, 2020; Romanowska et al., 2023; Patrick, 2024). Looking ahead, the integration of artificial intelligence—especially machine learning and expert systems—holds promise for further enhancing archaeological simulations, enabling more dynamic hypothesis testing, automated pattern recognition, and adaptive modeling of past human behaviors. As these technologies mature, they may offer new methodological frameworks for interpreting incomplete or uncertain archaeological data, pushing the boundaries of how we reconstruct and understand the past.

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[1] "Simulacrum" and "Simulation" are concepts that may seem similar but have important differences, especially in the field of philosophy. A Simulacrum refers to a copy or imitation of something that already exists. It is a representation that may not have a direct relationship with the original reality but still tries to replicate it. On the other hand, Simulation is the process of imitating or replicating a system or reality. Simulation attempts to reproduce the essential characteristics of something to study or predict its behavior. Simulation can be used in various fields such as science, engineering, education, and entertainment.

[2] Agent Sheets, AndroMeta, AnyLogic, Ascape, Breve, Cormas, DEVS, Ecolab, FLAME, JAS, LSD, MAML, MATSim, MASON, MASS, MetaABM, MIMOSE, MobiDyc, Modeling4all, Net Logo, Open Starlogo, Repast, Repast Simphony, SimPack, Simpy, SOARS, Starlogo, SugarScape, Swarm, VisualBots and Xholon.

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Digital Marketing in the Promotion of Cultural Heritage: The Case of the City of Ammaia

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Abstract

The rapid advance of digital technologies and media has required cultural institutions to adapt to this new reality. However, many remain unaware of this requirement or face limitations in terms of resources and technical knowledge, which makes it difficult to digitise their activities and define an integrated digital marketing and communication strategy. As this is still a recent reality that requires organisations to adapt, it is necessary to carry out studies that support decision-makers in their decision-making processes and contribute to furthering scientific knowledge in this area, especially with regard to smaller cultural institutions or those located in sparsely populated territories. Thus, the main objective of this study is to analyse the digital marketing and communication strategy of a cultural institution in Portugal, namely the Cidade de Ammaia Foundation. Based on this case study, a mixed methodology was adopted, which included analysing data available online, in particular on the Google and Bing search engines, as well as on the Google Business Profile platform, and conducting a semi-structured interview. The results indicated that although the City of Ammaia Foundation is present on some digital channels, it has not devised a digital marketing and communication strategy, mainly due to a lack of technical knowledge and relevant background information that hinders its realisation.

Keywords: Cultural, Digital marketing, Ammaia, Portugal, Archaeological heritage

1. Introduction

The digital age has brought with it countless challenges and opportunities with regard to the preservation and promotion of cultural heritage, understood as the collective memory of societies, embodying their traditions, history and identity (Lin et al., 2024). The revolutionary impact of digital technologies has been felt significantly in the field of cultural heritage promotion, extending to its various types, such as archaeological heritage (Volpe, 2020). Digital technologies have the potential to transform the entire value chain model of cultural heritage institutions, encompassing the recording and digitization of tangible and intangible heritage, ensuring its long-term preservation, adopting innovative digital research methods, and using digital platforms that connect people around the world with digital heritage objects (Münster et al., 2024). This new reality calls for innovative approaches that reconcile technology and memory, enabling the democratisation of access to culture and the enjoyment of cultural heritage that is distant, inaccessible or no longer physically exists (Valzano & Mannino, 2020).

Among these innovative new tools and media used for the preservation and promotion of cultural heritage are digital presentations, websites, online platforms and content with open access and collaboration, online libraries and archives, virtual tours and exhibitions, social media presence, 3D exhibitions, 3D restorations, 3D models and 3D exhibitions, on-site multimedia screens in museums, digital ticket reservations and online shops, live online events, online newsletters, multimedia, virtual reality and augmented reality, games, smart and educational mobile phone applications (Todorova-Ekmekci, 2021). These tools have become essential in enhancing cultural heritage by enabling immersive experiences for diverse audiences, promoting real-time dialogue and fostering a deeper emotional connection with heritage (Liu et al., 2020). Furthermore, digital channels enable connections to other heritage and accelerate the creation of new artistic works, unearthing new narratives (Münster et al., 2024). However, scientific studies in this area are limited, with few studies looking at the marketing of cultural and archaeological heritage in digital media.

This study aims to analyse the digital presence and marketing strategy of a cultural institution in Portugal, understanding the dissemination and safeguarding of heritage through digital means and promoting critical reflection on the challenges and consequences of digitisation in the context of cultural heritage. The research focuses on Cidade de Ammaia Foundation, whose mission to conserve and enhance Roman heritage in Portugal has been expanding into the digital realm.

This paper begins with a literature review on cultural and digital marketing, as well as search engine optimisation (SEO) and the Google Business Profile platform. It then describes the methodology used in the empirical study, presenting and discussing the main results. Finally, the conclusions, limitations of the study and suggestions for future research are presented.

2. Cultural Marketing and Digital

Kotler & Armstrong (2023) defines marketing as "engaging customers and managing relationships with them", creating a reciprocal cycle of customer-company and company-customer value". Lindon et al. (2000) mention that marketing seeks to understand the market, create products or services that satisfy customer needs and distribute and communicate them in order to create value. Following this concept, cultural marketing has emerged, promoting strategies for the dissemination of culture, art and its artists, the spaces and media in which they operate, and seeks to respond to and create needs in the public in order to attract visitors (Marecos, 2009).

Philip Kotler, in his book “Marketing Management: Analysis, Planning, and Control”, published in 1967, referred for the first time to the subject of marketing for cultural companies; this first approach to cultural marketing sought to identify the main marketing problems faced by cultural managers at the time, especially with regard to the difficulties of raising funds and investments, in the face of the growing competitive pressure that was beginning to be felt more intensely. In the 1980s, there was a fundamental change in the business culture of the arts and culture world, with the emergence of a new operational logic based on the product-public dichotomy (Kotler & Armstrong, 2023).

For Colbert (2015), cultural companies must adopt an operating model from the outset that incorporates the characteristic elements of a coherent and integrated marketing strategy, by redefining the marketing orientation of the cultural company in a different way from conventional product and service companies; in this case, the cultural manager seeks out consumers who are attracted to the product, thus inverting the usual logic of the process. Lampel & Germain (2016) points to the existence of several polarities that must be included in the program of any cultural management activity: values explicitly related to the arts must be reconciled with the economic viability of each project, they must also be innovative without, however, departing from the similar models on which they are based, they must consider the demand expressed by the market and, at the same time, seek to intervene creatively in the expansion of that same market. Finally, they must develop creative systems to support and market cultural goods, without interfering with the processes of individual inspiration that are at the root of value creation in the cultural industry.

Cultural management always faced financial limitations, lack of private and state support or accusations of elitism. The solutions will always depend on the type of product or service in question, but a number of elements can be listed: (1) hiring qualified managers; (2) improving levels of loyalty to brands or events; (3) launching complementary products or services; (4) establishing partnerships to obtain support and funding; (5) working on brands (branding or rebranding processes); (6) carefully selecting communication actions; (7) identifying, involving and engaging stakeholders; (8) establishing collaboration protocols with similar institutions; (9) encouraging the implementation of creative financing solutions; and (10) exhaustively, rigorously and independently evaluating the impact of marketing campaigns (Google, 2025a).

In recent decades, technology has revolutionized marketing, providing this science with new ways of selling and buying products/services, through the internet, changing the way the company relates to the market and the public (Lindon et al., 2000), and with knowledge that allows it to personalize experiences (Kotler & Armstrong, 2023).

Digital marketing thus emerged, as the utilization of electronic media to promote products or services into the market with the main objective of attracting customers and allow them to interact with the brand through digital media (Yasmin et al., 2015).

Addressing cultural marketing necessarily implies understanding its digital dimension, which nowadays, in developed economies, seems intrinsic to any person or entity. Digital marketing is therefore a tool with great competitive potential in the market, as it accompanies consumers through platforms connected to the internet with the aim of building brand loyalty, understanding their needs, desires and consumption habits and strengthening brand recall, using regular publications and sales promotions to give it visibility (Borges, et al., 2013).

Digital marketing strengthens a close relationship with consumers, promoting continuous interaction between them and the brand. This sustained process contributes to positive brand recognition, consolidating its relationship with consumers (Borges et al., 2013).

In the context of cultural marketing, the integration of digital marketing not only extends the reach of brands but also allows for the implementation of more effective and targeted strategies. Marketing strategies, which can be defined as the way in which the marketing function organizes its activities to achieve the organization’s objectives (Andreasen & Kotler, 1991), play a fundamental role in this process, as they guide the way brands communicate, interact and create value for their target audience.

Among the main digital marketing strategies mentioned by Yasmin et al. (2015) is content marketing, which aims to attract and engage consumers by creating and sharing relevant information and storytelling, in order to inform, win over and influence the consumer's purchasing decision (Torres, 2010). Another key strategy is social media marketing, which promotes proximity and continuous interaction with the public. As Torres (2010) points out, social networks are built on continuous and lasting relationships between people and communities, and have an intrinsic value, as they allow for the wide dissemination of information. In addition, email marketing has emerged as an effective tool for sending messages directly to a specific list of contacts, with the purpose of disseminating promotions and information aligned with the consumer's profile and preferences, reinforcing personalized communication and the relationship with the brand. Similarly, SEO (Search Engine Optimization) and paid advertising are essential strategies for maximizing brand visibility on search engines and social networks, ensuring that messages reach the right audience at the right time. These approaches boost the impact and effectiveness of digital marketing campaigns, distinguishing them from traditional marketing in that they allow companies to communicate at a lower cost, but with a greater capacity for dissemination (Torres, 2010). As Kotler and Kartajaya (2017) point out, search engine optimization strategies have emerged as crucial elements for increasing the visibility and online presence of organizations, and should also be applied by cultural institutions.

2. Search Engine Optimization and Google Business Profile

According to Jerkovic (2010), SEO is defined as a set of activities necessary to generate a high volume of successful references from search engines and web directories, with the aim of increasing the visibility of a website. Grapon & Couzin. (2011) state that the term describes a diverse set of activities that you can perform to increase the number of desirable visitors who come to your website via search engines.

SEO techniques aim to improve the positioning of websites in search results, which are currently the main way of retrieving electronic information. The implementation of this concept has increased, especially in the commercial sector, strengthening brands, products and services online and increasing companies' profit margins. Being among the first search results for users becomes a competitive advantage for all organizations (Oliveira et al., 2011), including cultural institutions. Currently, positioning depends on the relevance determined by algorithms, criteria that define the ranking order of websites in search engines. These criteria are influenced by a number of internal factors, such as the structure of the website itself, the appropriate use of tags and the indexing of

keywords; and external factors, such as the relationship with other websites, the number of links and accesses. Search effectiveness is influenced by the skill of the user and the ability of the search engine to understand their needs (Oliveira et al., 2011). For SEO professionals, it is essential to understand the client's needs, considering not only the techniques but also the business context.

In the context of local SEO, the Google Business Profile platform, formerly known as Google My Business, is a free tool from Google, Inc. that allows organizations to optimize their online presence in geolocated searches. Through this tool, brands can provide users with all the information about their activity, thus helping organization to get more clicks, facilitate interaction with the public and strengthen its digital visibility. The use of this platform may be very beneficial for organizations, as it (1) positions them at the top of Google search results, (2) increases visibility, (3) highlights important information about the organization, (4) gets more traffic to the website, (5) attracts more people to the organization's physical spaces, (6) keeps customers and potential customers informed, (7) promotes user interaction with the organization, (8) increases the credibility of the organization and/or brand, as it conveys greater seriousness, (9) provides an easy and practical browsing experience and (10) improves performance and ranking through SEO (Google, 2025).

To optimize your presence on this platform, you should take advantage of all the possibilities offered by the tool (Google Business Profile):

a) Choose a business category – after it describe the products or services you offer, acting as keywords for users whenever searched on Google;

b) General information – brief description of your business, contacts and working times;

c) Location – by entering the address, the exact location will appear in the search results, along with a local map, allowing you to navigate in real time via Google Maps, increasing visibility;

d) Photographs – or videos, by the organization but also by third parties;

e) Reviews – many will base their decisions on the reviews and how the organization responds;

f) Questions and Answers (Q&A);

g) Publications – and update statuses, a logo (or brand), as well as maintaining regularity, in order to keep customers and remind them of the organization (Google, 2025).

3. Methodology

This research aims to analyse the digital marketing strategy of a cultural institution in Portugal, namely the Cidade de Ammaia Foundation, through SEO and Google Business Profile. To this end, two different methodologies were used. Firstly, data obtained through search engines (Google and Bing) and Google Business Profile was analysed with criteria previously defined by the researchers. Subsequently, an interview was conducted with Joaquim Carvalho (I), one of the organisation’s communication managers. The study is based on a single case study, which makes it possible to analyse data on a contemporary phenomenon in its real context (Yin, 1994). The Cidade de Ammaia

Foundation was chosen because of its commitment to the conservation and valorisation of Roman heritage in Portugal, a commitment that has been extended to the digital domain.

The analysis was carried out on the 10th January 2024. With regard to the institution's positioning on search engines, Google (https://www.google.com/) and Bing (https://www.bing.com/) were selected, as they are the most widely used in Portugal, with market shares of 89.74% and 4%, respectively, in January 2024 (Statcounter, 2025). The search terms considered were 'Fundação Cidade de Ammaia' and 'Ammaia', as they were thought to be the most used by potential visitors, coinciding with the official name of the institution. However, the exclusive use of these two search terms may constitute a limitation of the study, as it may not fully reflect the diversity of search behaviours and alternative queries used by the public.

The analysis carried out on the Google Business Profile was based on the following parameters being considered as analysis dimensions: i) category; ii) description; iii) address; iv) contacts; v) opening hours; vi) products; vii) location; viii) photographs; ix) evaluations; x) questions and answers; xi) publications.

The interview, which took place on the 13th January 2024, was semi-structured, based on a previous set of questions, the topics of which are shown in Table 1.

Table 1. Interview topics.

Script	Interview Focus	Question Topics	Organization/ Participant	Date
1	General and detailed information; In-depth internal perspective	(Q1) Ammaia Foundation Characterisation; (Q2) Objectives of the digital marketing strategy; (Q3) Target audience; (Q4) Digital channels; (Q5) Adoption of technologies in the future.	Joaquim Carvalho	13 January 2024

4. Findings

4.1. Amaia characterization

The Cidade de Ammaia Foundation, established in 1997 with the aim of safeguarding the ruins of the ancient Roman city of Ammaia, is dedicated to promoting cultural, educational, scientific and philanthropic activities.

The Roman city of Ammaia, located in the Serra de São Mamede Natural Park (Marvão), represents the most significant vestige of the Roman presence in the north of Alentejo. Despite being classified as a National Monument in 1949, it remained in a state of abandonment until the institution was founded. Excavations that began in 1994 revealed urban structures such as the South Gate, the Cardo Maximus, the Forum, thermal complexes and a temple with a podivm.

The museum, housed in the former Quinta do Deão, exhibits a vast archaeological collection, including coins, ceramics, glass and epigraphs, divided into thematic sections. The conservation and restoration laboratory, active since 2009, adopts methodologies based on ECCO principles, ensuring

the preservation of movable heritage through minimal, reversible interventions that are compatible with the original materials.

The Foundation was responsible for the project “Ammaia, Centro Português para a Descoberta da Cultura Romana”, with a focus on enhancing the city as an archaeological tourist destination through investments in conservation, restoration, infrastructure and heritage interpretation.

At the same time, it took part in the European Radio-Past project, which aimed to implement non-invasive archaeological diagnostic methodologies (geophysics, aerial photography, historical cartography), promoting the interpretation of underground realities and the accessible visualisation of invisible archaeological contexts. This international consortium has fostered a sustainable approach to the research and management of heritage sites (Joaquim Carvalho, personal communication).

4.2. Digital Marketing Strategy Analysis

Analysing the presence of Cidade de Ammaia Foundation in the digital world involves looking at various digital platforms. This study focused on analysing its presence on search engines, since these are one of the most used tools on a daily basis by Internet users, including travellers when planning and experiencing their trips. Presence, and especially good positioning, on search engines gives institutions greater visibility and increases the likelihood of visits; in fact, around 90 per cent of the world's population only consults the results displayed on the first page of a search and 72 per cent of consumers who carry out a local search visit an establishment within a five-mile radius of their current location (Arts Council England, 2025).

In this context, the terms ‘Fundação Cidade de Ammaia’ and ‘Ammaia’ were searched on Google and Bing, and the results showed that, for the term ‘Ammaia City Foundation’, 6,220 results were obtained on Google and 1,730,000 on Bing, while for ‘Ammaia’ there were 107,000 results on Google and 31,100 on Bing, as shown in Table 2. The foundation's official website (http://www.ammaia.pt/) was found to be in first position on both search engines, which shows that it is well positioned. However, it should be noted that this analysis only covers the terms corresponding to the official name of the institution, and a more comprehensive assessment in the field of heritage promotion would require the use of other search terms, such as ‘archaeological heritage’. Considering that the website is often the institution's digital ‘gateway’, its presentation should be attractive, functional and provide up-to-date information. However, this has not been the case and, according to the interviewee, ‘the digital channels used by the foundation are search engines, the website and, currently, more frequently social networks, namely Facebook and Instagram’.

Considering the results obtained, Ammaia is well positioned on collaborative platforms such as Wikipedia. This presence is an important opportunity, as it is within the reach of the institution's employees to contribute to improving the information, making the pages more attractive and up-to-date. In addition to updating textual content, it is important to reinforce multimedia content, such as adding three-dimensional images that reconstitute the city and its most emblematic buildings, thus

enhancing the user experience and knowledge about heritage. Also noteworthy in this context is the report published in National Geographic magazine, an internationally renowned multimedia brand, recognised for the high quality of its content in the area of archaeological heritage, not only in textual format, but above all for the excellence of its photographic productions. This publication highlights the growing importance of disseminating cultural and archaeological heritage through online media, contributing to the international projection of the Cidade de Ammaia Foundation and strengthening its presence in the digital environment.

Table 2. First three results for the terms 'Ammaia City Foundation' and 'Ammaia'.

	Search terms		
	Fundação Cidade de Ammaia		Ammaia
Search engine	Results		
Google	1st	Fundação Ammaia http://www.ammaia.pt/	Fundação Ammaia http://www.ammaia.pt/
	2nd	Wikipédia https://pt.wikipedia.org/wiki/Ammaia	Wikipédia https://en.wikipedia.org/wiki/Roman_villa_of_Ammaia
	3rd	National Geographic https://www.nationalgeographic.pt/historia/a-cidade-luso-romana-ammaia_2386	Wikipédia https://pt.wikipedia.org/wiki/Ammaia
Bing	1st	Fundação Ammaia http://www.ammaia.pt/	Fundação Ammaia http://www.ammaia.pt/
	2nd	National Geographic https://www.nationalgeographic.pt/historia/a-cidade-luso-romana-ammaia_2386	Wikipédia https://pt.wikipedia.org/wiki/Ammaia
	3rd	Wikipédia https://pt.wikipedia.org/wiki/Ammaia	National Geographic https://www.nationalgeographic.pt/historia/a-cidade-luso-romana-ammaia_2386

Source: Own elaboration using data from the Google and Bing search engines.

In addition, Ammaia is also present on the Google Business Profile, where it is identified as 'Ruins of the Roman City of Ammaia'. Here, the institution is also well positioned, as when you search for the foundation on search engines, this information is available in the right-hand corner, and also accessible via Google Maps, which is particularly useful for users looking for local information (Figure 1). Taking into account the dimensions provided by this tool, and as shown in Table 2, it was found that the institution provides complete and up-to-date information in the different functionalities, reinforcing its digital presence. Particularly noteworthy is the high number of user evaluations (1,429 evaluations), which enrich this presence with comments and textual and multimedia content, contributing to a positive perception among the public and enhancing the heritage that the foundation preserves.

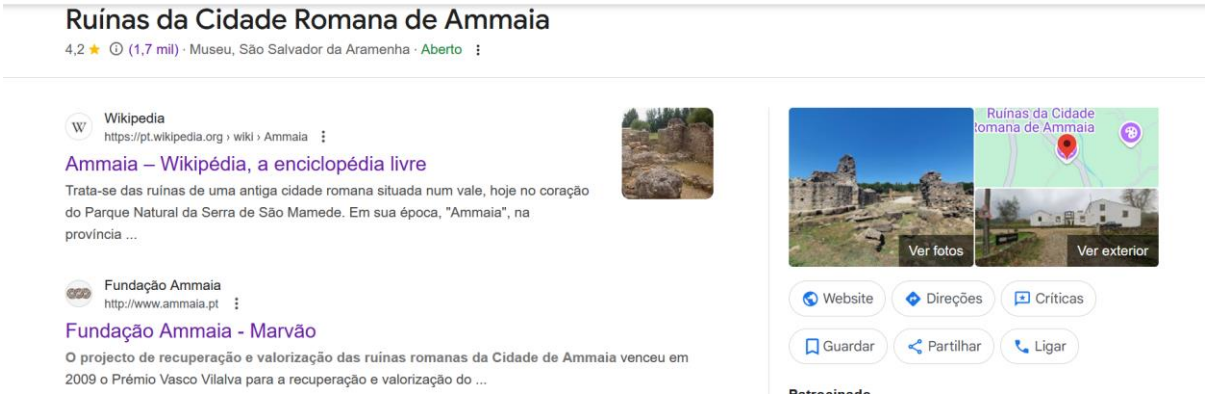

Figure1. Search engine result from Google for the term "Ammaia"
Source: Google (2025b)

However, in our opinion, this data could be used to better understand the behaviour of the target public at the Ammaia Foundation, which is not happening. When asked about the characteristics of Ammaia's target audience, the interviewee mentioned that 'target audiences are not defined in a specialised way, they correspond mainly to the general public without any prior orientation' (...) 'We have never made this assessment, so we are currently unable to present the characteristics of the target audience'. Regarding the identification and segmentation of the target public, the interviewer said that 'so far we haven't identified and segmented the public, taking into account that this is a museum and ruins, normally the visits we have are more related to tourism and visits to the region, although we already have the perception that there is an increasing number of public with a particular taste for historical and archaeological aspects'.

With regard to the digital marketing strategy of the City of Ammaia, the interviewee was asked about the Foundation's main objectives in the field of digital marketing, and he replied that 'for the Ammaia Foundation, the main objectives in the field of digital marketing are to create an institutional and heritage image capable of giving the institution and the ruins of the Roman city greater notoriety and awareness among the general public. At the same time, this will not only allow for proper recognition but also the possibility of channelling and attracting more visitors to the museum and ruins.'

Regarding the creation of digital content, the use of data/metrics to develop marketing actions and the management of user engagement on social networks, the interviewee said that 'they try to create content adapted to digital marketing tools, but without any knowledge of the most fruitful or beneficial way of doing so' (...) 'we consult the number of views on social networks in relation to these contents/publications, but we have never carried out studies applied to this issue'. Still on this issue, he said that 'the management of user involvement is quite cordial and encouraging with regard to the content shared on social networks; however, we think we could and should improve a lot on this issue'.

Table 3. Dimensions and results for 'Ammaia City Foundation' on Google Business Profile.

Dimensions	Results
Category	It is called 'City of Ammaia (ruins)' and is classified as a 'Historical place museum in Portugal'.
Description	Provides a brief description of the tourist attraction using Wikipedia.
Address	Provides up-to-date information on the Museum's address.
Contacts	Provides up-to-date telephone contact information only.
Timetable	Provides the timetable for every day of the week and also for festive periods. Provides a real-time graph of attendance.
Products	No information available, although there are products for sale in the museum.
Location	Provides up-to-date information on the Museum's address and coordinates. The connection to Google Maps is working and allows directions to be obtained, which is particularly important given the Museum's remote location, but also due to the dispersal of tourist elements in the archaeological field.
Photographs	Thousands of multimedia records (photographs and videos) are available, the vast majority of them from visitors (not from the organisation), and it is also possible to access content via Street View and 360º.
Reviews	It has 1,429 reviews, achieving a score of 4.2 out of 5 stars (as of 10 January 2024).
Questions and Answers (Q&A)	The questions asked have been answered by the institution or by other visitors.
Publications	There is multimedia content published by the institution, in line with that available on the website and official social networks. Up-to-date and useful information for visitors.

Source: Own elaboration

Finally, when asked what the Foundation's prospects were with regard to joining new digital marketing platforms or technologies, the interviewee said that 'in view of the ongoing digital evolution, it is very likely that our institution will join other platforms or technologies in order to be better inserted in this technological field'.

In view of the responses obtained, we can conclude that the Cidade de Ammaia Foundation has outlined ambitious tasks in the field of digital marketing, albeit without a concrete strategy, developed through the interdisciplinary co-operation of staff and aimed at establishing a robust online presence through the different marketing channels, to strengthen its institutional image and raise awareness of the ruins of the Roman city. Moreover, the interaction between different areas of digital marketing and their connections with disciplines such as tourism, culture and communication could be explored further, in order to enhance the effectiveness and coherence of the Foundation's digital actions.

However, the lack of specific segmentation of target audiences reveals a more generic approach, centred mainly on the tourist public. The use of digital channels, such as the institution's website and social networks, is evident, although the creation of digital content is recognised as an area that requires improvement, given the lack of specialist knowledge. These findings are consistent with those identified by Dinis et al. (2020), in their analysis of the digital presence of the destination management organization of Alentejo and Ribatejo, the region in which the city of Ammaia is located, where similar limitations were identified. Furthermore, they align with the conclusions of Fontes et al. (2024), who, in their study on the wine tourism segment in the Trás-os-Montes and Dão regions, underscore the strategic importance of fostering synergies between wine tourism and digital marketing, as a means of enhancing the promotion of businesses and the visibility of service offerings within the regional context.

User engagement on social media is described as cordial, but the Foundation is aware of the need for significant improvements in this regard. Although the current metrics are centred on social media and website views, the institution has not yet conducted more in-depth studies to assess the effectiveness of its digital marketing strategies. Furthermore, in the face of digital evolution, the Foundation expresses a positive attitude towards embracing new platforms and technologies, showing a willingness to embrace innovation in the digital context. This overview reveals a commitment to strengthening the City of Ammaia Foundation's online presence, but also highlights specific areas that require ongoing attention and development.

This study reveals implications for the Cidade de Ammaia Foundation and other cultural institutions with similar characteristics, highlighting the need to strongly invest in the development of a holistic digital strategy that integrates various marketing channels. At the core of this strategy lies the necessity to understand the target audiences of these institutions, who seek information about cultural heritage through digital media, in order to create specialised content that fosters more effective and targeted communication. Furthermore, cultural institutions such as the Cidade de Ammaia Foundation should invest in the improvement and updating of content across digital channels, as well as in the monitoring and evaluation of their digital activities. To this end, the importance of enhancing human resources' skills and promoting interdisciplinary and interinstitutional collaborations is emphasised, as these can foster synergies between tourism, culture and technology, thereby strengthening the promotion and valorisation of cultural heritage.

5. Conclusion

The Cidade de Ammaia Foundation aims to become an important archaeological tourist destination and digital marketing tools are currently essential to the success of this endeavour given the city was devastated by the wear and tear of time. This study aims to analyse its online presence and digital marketing strategy adopted by the institution, using a mixed research methodology.

After analysing its presence on Google and Bing, we can conclude that the institution's website is well positioned, occupying the first three positions in searches carried out using the name of the

foundation. However, there are areas that could be improved, especially with regard to the presentation of the website and other digital channels, for example by reinforcing the use of images and multimedia content, such as three-dimensional ones that reconstitute the city and its most emblematic buildings.

On Google Business Profile, where it is called ‘City of Ammaia (ruins)’, the organisation is very well positioned, taking full advantage of the multiple functionalities of this tool, with the completeness of the information provided by users contributing significantly to this positioning.

The Cidade de Ammaia Foundation aspires to establish itself as a reference in archaeological tourism. In this context, digital marketing is not merely a complementary tool, but a strategic imperative—especially considering the invisibility imposed by the site's physical degradation over time. This study has shown that, while the Foundation enjoys strong positioning on search engines and leverages tools like Google Business Profile effectively, its digital presence remains largely underexploited. The website and digital channels lack the immersive and engaging content that is increasingly expected by cultural tourists, particularly the use of 3D reconstructions and dynamic multimedia that could bridge the gap between past and present.

With regard to the digital marketing strategy, it can be concluded that the Foundation does not have a well-defined digital strategy, and even shows some ignorance of its target audience. The institution itself recognises the need to invest in significant improvements in this area and to carry out more in-depth studies. On the other hand, the metrics currently used by the Foundation are essentially limited to monitoring the number of views on social networks. This situation reveals some limitations at the strategic level, jeopardising the possibility of making informed and timely decisions.

Of particular concern is the absence of a defined digital marketing strategy and the limited use of performance metrics suggest a reactive rather than proactive approach to audience engagement. This reveals a structural weakness that undermines the Foundation’s potential to capitalise on digital visibility to drive visitation, education, and support. Moreover, the superficial nature of current metrics (e.g., social media views) impedes data-driven decision-making, which is essential in an increasingly competitive cultural tourism landscape.

Nevertheless, the institution’s openness to adopting new technologies offers a foundation for strategic transformation. To move forward, the Foundation must prioritise the development of a comprehensive digital marketing strategy tailored to its target audiences, invest in content that conveys the archaeological value of the site in engaging ways, and adopt robust analytics tools to monitor and adjust its digital performance in real time.

A limitation of the study is the search terms used to analyse the Foundation's positioning in search engines. In addition, the interview could have been more in-depth and enlightening, especially with regard to the use of digital channels such as the website and social networks. These limitations could serve as a basis for future studies, allowing for a more comprehensive exploration of the institution's digital marketing practices and its online positioning in the field of cultural heritage and tourism. Future research could build upon this work by expanding the scope of search queries analysed and

conducting more detailed interviews with stakeholders involved in digital operations. Such studies would help refine the understanding of how cultural heritage institutions like the Cidade de Ammaia Foundation can leverage digital tools not just for visibility, but for meaningful, sustained engagement with global audiences.

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Playing with Diplomatic Culture: A Comparative Study of Esports Policies in South Korea and Brazil

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Abstract
This article proposes an analysis of public policies aimed at electronic sports (esports) as a tool for cultural diplomacy in South Korea and Brazil. Its objective is to determine whether esports are used by these states as a foreign policy resource to achieve absolute gains in the international sphere, based on a qualitative analysis of data obtained from South Korean and Brazilian legislation on the subject. The corpus consists of 50 documents addressing this theme, retrieved from the official websites of the South Korean and Brazilian governments. Among the main findings, the South Korean government's consolidated approach to esports stands out. In contrast, Brazil lacks a public policy consensus regarding the subject. However, some international public prestige gains are achieved, even though the state's foundations regarding esports remain incipient. This study presents originality by exploring potential connections between the field of International Relations and the universe of electronic sports, a growing expression of contemporary youth culture.

Keywords *Esports, Foreign policy, Cultural diplomacy, Brazil, South Korea*

1. Introduction

As a consequence of the recurring crises of capitalism, the COVID-19 pandemic intensified market concentration processes and the commercialization of gaming. Although impacted, the gaming industry took advantage of the global crisis as an opportunity to reinvent itself, gain social legitimacy, and demonstrate its resilience in a pandemic scenario marked by uncertainty. Major companies in the video game and esports industries thrived during this period. In particular, esports experienced a moment of prominence and a unique opportunity for social self-affirmation.

Several authors discuss concepts to define the phenomenon of esports. Wagner (2006) states that they are a field of sports activities in which people develop and train physical or mental skills using Information and Communication Technologies (ICTs). Macedo (2023a), on the other hand, contributes to the construction of the concept by highlighting the importance of understanding esports more broadly than is commonly discussed in the academic mainstream. He argues that not only the professionalized practice of digital games should be considered esports, but other forms should also be included, such as amateur, recreational (casual), community, and university competitions.

The fact is that esports are now a global phenomenon with varied repercussions and appropriations across different parts of the world (Jin, 2021), depending on socioeconomic contexts,

geopolitical projects, and the interests of game developers, countries, and controlling groups. Within this context, the central question guiding this study is: are esports used as a tool of foreign policy[i]? Our intention is to verify the existence of a strategy based on international gains[ii] through esports in two countries with very different realities in this practice: South Korea and Brazil.

A key motivation for this research emerged from the perception that sports practices, undeniably recognized within the cultural spectrum of states, serve as vehicles for executing foreign policy. The Qatar FIFA World Cup 2022, for example, represents the culmination of a long-term process in which Gulf nations have invested in sporting events and mega-events, sponsored franchises, companies, and various sports clubs, and purchased major football clubs as part of sophisticated geopolitical strategies (Koch, 2018).

Against this backdrop, this study is justified by the growing relevance of the digital gaming industry and, especially, the rise of esports as a form of sociocultural expression for a wide range of actors. This is further reinforced by the fact that, at the intersection of Communication and International Relations studies on culture and foreign policy constitute a growing field, yet there is a scarcity of works that specifically analyze esports, particularly as a potential tool of state foreign policy.

The central objective of this research, therefore, is to assess whether South Korea and Brazil adopt international success in esports as part of their cultural diplomacy strategy. To this end, the specific objectives include: (1) contextualizing cultural diplomacy as a tool of foreign policy; (2) analyzing Brazilian and South Korean legislation regarding esports practices; and (3) identifying the absolute international gains these countries have achieved through esports. Using a comparative case study method, we aim to examine the public policies of Brazil and South Korea related to esports and their consequences on the international stage. The collected data were classified into five categories (alliances and partnerships; global development; economic integration; innovation and technology; public prestige) to determine whether they are in any way related to foreign policy gains.

The study is structured into six sections. Initially, we provide a contextualization of esports, followed by a theoretical framework that seeks to structure the study’s argument. The fourth section discusses the methodology used in this research, while the following section presents the results of each case analysis and a synthesis of the findings. Finally, the last section presents the concluding remarks.

2. Brief context of esports

Esports have a long history worldwide. Some of the earliest video game competitions were documented in Asia, North America, and Latin America, in countries such as Japan, the United States, and Brazil. Since then, the development of arcades and the first home consoles during the 1980s has increasingly fueled the popularity of video game competitions. Taylor (2012) points to a pivotal shift in the competitive aspect of gaming experiences with the implementation of a user score ranking system.

Since then, arcade and console competitions have expanded into Local Arena Network (LAN) groups, incorporating new styles based on fighting and shooting games into the competitive scene.

To understand the popularization of these practices, it is essential to consider the emergence of cultural manifestations stemming from a new social structure, driven by the development of information technology, particularly the internet. This accelerated globalization and enabled individuals from all regions of the world to interact through digital screens. Castells (2000), for example, referred to this new organizing structure as the "network society," while more recently, authors like Van Dijck, Poell, and De Waal (2018) have identified a new transformation called the "platform society."

Furthermore, the growth of the gaming industry is directly linked to the increasing access of new devices for consuming gaming experiences, driven by the widespread use of smartphones, computers, streaming platforms, and consoles. This dynamic has significantly expanded the number of potential digital game consumers. Looking at the financial figures of the gaming industry and ecosystem also helps illustrate the scale this market has reached in the global economy. It is now a well-established fact that this sector has become the largest entertainment industry, surpassing revenue from television, film, and music.

Within digital games, however, esports still represent a relatively small portion of total revenue, surpassing the US$1 billion mark only in 2020 – small when compared to the +US$100 billion of the digital games sector in its entirety (Newzoo, 2020). Despite this, esports have gained immense popularity in many regions, including Brazil. Historic sports entities such as Clube de Regatas do Flamengo, Sport Club Corinthians Paulista, and renowned Brazilian football athletes have already participated in the esports ecosystem by sponsoring professional teams (Newzoo & Esports Bar, 2018). Gradually, esports are securing a prominent place within the gaming industry, becoming relevant elements in contemporary entertainment, leisure, the market, culture, and politics.

Beyond fans, esports events involve several other key players. Among them are major technology corporations that act as sponsors for both competitions and professional teams, which are composed of professional players, known as pro-players, who compete in tournaments. Additionally, there are presenters, commentators, tournament organizers, and coaching staff who contribute to the structure of the competitive scene.

3. Foreign Policy and National Interests

Foreign policy or a state's external policy, according to Figueira (2017), is a set of actions undertaken by a state in the international arena. It not only reflects the country's intended interests or its global conduct but should also encompass strategies for the state's engagement in various spheres of international life. To achieve foreign policy objectives, states seek to obtain gains and define their interests in terms of individual benefits (Grieco, 1988). Cai (2011) establishes that the pursuit of absolute gains is one of the key focuses of contemporary neoliberal’s foreign policy and

defines it as the assessment of the benefits of an international action, measuring its overall effect, considering dimensions such as power, security, economy, and culture.

According to Pinto (2011), following contemporary theoretical approaches in International Relations, five areas can be identified where a state may direct its foreign policy to achieve absolute gains: (i) the institutional field of alliances and partnerships; (ii) governance capacity for global development; (iii) economic integration; (iv) innovation and technology; and (v) public prestige. Table 1 provides a more detailed overview of the activities related to each of these fields.

Table 1: Spheres of Absolute Gains in Foreign Policy

Spheres of Absolute Gains in Foreign Policy	Description
Alliances and partnerships	• Maintenance of the State's commitment to international institutions; • Renewal of alliances with traditionally partner States.
Global development	• Provision of support for the socioeconomic development of poorer countries.
Economic Integration	• Meet the State's commercial needs; • Reduce barriers and facilitate cooperation with other States in Strategic sectors.
Innovation and technology	• Ensure access to contemporary and sustainable technology
Public prestige	• Influencing international Perception of the State through unofficial diplomatic actions.

One constant goal of a country is the formulation of a foreign policy that relies on the attainment of power. Although it is a highly contested concept, for Joseph Nye (2011) power can be broadly understood as the ability to influence others to achieve desired outcomes. It is important to add, as well, that no one is able to possess it because power is constantly contested and is an intrinsic component of social relations, which can be circumscribed in the form of cultural or political hegemony (Digeser, 1992).

There is one particular form of power, coined as soft power by Nye (2004), that is based not on coercion – like classic forms of power, materialized by expansionist empires through coercion, for example –, but on a seductive articulation of institutions, standards of living, customs, cultures, or ideologies that seeks to co-opt people or entities into wanting to be like them rather than forcing them to do so (Martinelli, 2016; Nye, 2004).

Despite appearing to be abstract, soft power allows a state to achieve its external objectives from the moment other countries desire to follow it, admiring its values, copying its example, and aspiring to the same level of its prosperity, openness, and freedom (Nye, 2014). A clear example of the effectiveness of this strategy can be seen in patterns exported by the United States, such as the famous American Way of Life – disseminated during the post-World War II period in the 20th century. In addition to generating a positive image for the country on the international stage, the model results in billions of dollars annually spent on consumer goods by those who are inspired by this standard of living (Martinelli, 2016).

To mention not only a Western case, other good example can be observed in the case of China and its Confucius Institute. While the country faces a position of distrust among the public opinion of many people in the Western world – largely due to historical and political legacies from the Cold War period and the current disputes against the US – the presence of the Confucius Institute in 146 countries (Confucius Institute, 2025), including Western powers such as Brazil, the United States, and Switzerland, represents a measure of Chinese soft power. This is because, through these institutions, people who once knew nothing about China – or worse, held a negatively stereotyped view of the country – now have the opportunity to learn its language and cultural customs, often in a way that is financially and logistically accessible.

4. Cultural Diplomacy Strategies: Sports as a Foreign Policy Tool

One way to build a foreign policy that aims to earn soft power among the international sphere is with cultural diplomacy strategies, which constitute the exchange of cultural aspects between nations and their people to ensure mutual understanding. We understand, as Macedo & Falcão (2019), that esports constitute a mixed phenomenon spanning the fields of entertainment, communication, and sports, establishing themselves as an element of contemporary digital culture. With this in mind, esports become a fruitful practice to the development of cultural diplomacy.

According to Mark (2009), cultural exchange, including the interchange of individuals between distinct countries, helps open effective communication channels between two or more nations. Goff (2013) argues that properly applied cultural diplomacy can tell a different story about a country[iii], explain aspects of a culture that would otherwise be incomprehensible to the outside world, and establish agreements that traditional diplomacy would not achieve. Among the objectives of cultural diplomacy, highlighted by Fan (2010), are the redefinition of national identity, the integration of political, cultural, economic, and sports activities into the image of the State, the promotion of national interests on the international stage, and, ultimately, the strengthening of a positive national image abroad.

Within the cultural sphere, sports are considered an effective means of interaction between countries, as many of their disciplines transcend borders and are practiced, watched, and valued by a plurality of individuals. The universal nature of sports introduces them as an effective tool for cultural diplomacy (Dubinsky, 2019).

However, the public prestige sought through the sports sector may be limited due to multiple factors. As argued by Haut et al. (2017), success in a particular sport is only valued in countries where that practice is common or appreciated. Conversely, it may be considered irrelevant in nations where the sport is neither traditionally practiced nor valued. Furthermore, aspects such as respect for rules, the promotion of fair play, and sports events marked by memorable stories can significantly impact a country's international image, either positively or negatively.

Although the discussion regarding the classification of esports within the realm of sports practices remains contested (Macedo, 2023a; Taylor, 2012), the phenomenon shares a certain universality, as

mentioned aboveiv. This is evident, as video gaming has become one of the most significant cultural industries in the world in recent years (Jin, 2010; Taylor, 2012), even featuring international competitions between different nations.

For example, in 2012 and 2013, the Chinese government demonstrated its intention to compete with South Korea in the esports sector by hosting the World Cyber Games (WCG), which at the time was one of the largest esports competitions in the world. Beneath the surface of this initiative, China displayed the power of its audience to the world and diverted public attention from recent scandals involving China's role in the global technology industry. These widely publicized cases included allegations of labor exploitation and precarious working conditions in factories (Szablewicz, 2016).

From this perspective and within this context, taking the Chinese case as an example, this study seeks to examine the Brazilian and South Korean contexts regarding the use of esports — by public authorities — as a strategic tool to achieve desired political, economic and cultural interests. To this end, we employ absolute gains theory in foreign policy as an analytical framework, along with the concept of cultural diplomacy, to classify and analyze the results obtained by both countries in their esports initiatives.

5. Methodological Procedures

The overall process applied in this study was, firstly, through a bibliographical research to understand the local context of Brazil and South Korea in the development of their esports scenario. In parallel, we also observed how the governments approached its sports (and esports) scenario in their foreign policy strategies, finding the concept of cultural diplomacy. After that, we conducted a documental research in the laws and regulations of Brazil and South Korea regarding esports, as detailed in this section. Lastly, we compared results achieved by both countries in the most important international competitions of the most watched esports games until 2023.

The strategy used to operationalize the research was the comparative case study (or multiple case study), an approach that involves observing a pattern of occurrences between two or more cases, aiming to compare different realities under the same conditions and theoretical frameworks in order to understand the context of each case (Yin, 2001). The subjects of this study, therefore, are the Brazilian and South Korean foreign policies and their relationship with esports.

The choice of these particular two countries is justified by the following facts: i) South Korea is widely known by its success in many esports titles, gathering some of the best players in the world, and seems to have a well structured environment to sustain local championships and form new successful players; ii) Brazil, on the other hand, appears to have international success in some titles, but not as hegemonic as South Korea, while its internal esports ecosystem appears to be more fragile in terms of infrastructure; iii) both countries have very different settings – geographical dimension, cultural aspects about gaming and population scale, for example. We think that by analyzing how the official government institutions approach the phenomenon can give us a hint about their international

performance and the absolute gains earned through their cultural diplomatic strategies (if they exist in this field).

The data collected were interpreted based on their classification into one of the following variables: 1) institutionalization – which institutions are responsible for the governance of esports in the country; 2) regulation – the set of national or regional policies surrounding the topic of esports; 3) economic integration – signs of economic cooperation between different institutions, groups and individual actors that permeate the esports scenario in each country; 4) international advertising strategies – official initiatives from the government that aim to advertise the local esports ecosystem to the world abroad; and 5) public prestige – unofficial actions that in any way gather prestige for the country through esports competitions. The choice of these five categories was based on the interpretation of the arguments in defense of absolute gains by Pinto (2011), as well as Cai (2011), addressed in the previous section and adapted to the context of esports and the concept of cultural diplomacy.

In addition, the analysis technique applied is of a documentary nature. To access official documents related to the legislative issues analyzed in the research, institutional websites of both countries were consulted: for Brazilian laws, the websites of the Federal Senate, the National Congress, and the Chamber of Deputies; for South Korean laws, the official website of the Ministry of Government Legislation and the Korean Legislation Research Institute. This stage was conducted between March 2 and 9, 2023. The survey used the keyword "esporte eletrônico", (for the portuguese websites) and “esports” (for the Korean websites in English) in the advanced search system of each selected website, without time period restrictions, including all types of documents (articles, laws, propositions, bills, and other related documents) in progress or completed. A total of 31 cases were found in Brazil, of which 27 documents and articles relevant to the research were analyzed. In South Korea, 20 results were found, of which 8 were analyzed as they were related to the topic. All documents that only addressed conventional sports were excluded.

During the bibliographic research phase, we identified that the agencies involved with the topic were distinct in both countries. Therefore, we searched for the same term "esports” with its Portuguese, English, and Korean variations on the websites of the Ministry of Foreign Affairs (MRE) of Brazil and the Ministry of Culture, Sports, and Tourism of South Korea in order to find diplomatic measures related to the topic. The search on the Brazilian website yielded 7 results, of which only 2 were relevant to the topic and were analyzed. The Korean website, on the other hand, provided 91 results, of which only 13 were relevant to the research and, therefore, were analyzed.

For obtaining information on state laws in Brazil, we searched for the keywords "esporte eletrônico," "e-sports," "esport," and "prática eletrônica esportiva" on the websites of the state assemblies and the "state laws" and "municipal laws" query repository, using the same filter specifications as for the search of national laws. Quotation marks were used to specify the terms searched in the search systems. As discussed in the results, the national government and the Ministry of Culture, Sports and Tourism centralize the regulations about esports in South Korea, thus, the search for province laws was not applicable to their case.

6. Presentation and Analysis of Results

6.1. Institutionalization

South Korea was one of the first countries in the world to institutionalize the practice of esports (Taylor, 2012). In a survey conducted by Thiborg (2009), only a few European and Asian countries had actors dedicated to organizing digital sports, with the Korea eSports Association (KeSPA) being a pioneering case. Currently, the organization has been working behind the scenes of the main esports leagues in the Asian country for over 20 years, strengthening its foundation through government support from the Ministry of Culture, Sports, and Tourism.

Beyond the ministry, South Korea's government view on digital games and the global role of the country in the sector is unified. In 2001, South Korean President Kim Dae-jung spoke at the opening of the WCG in Seoul, seizing the opportunity to express his expectations regarding how the event could support the global recognition of the country in the gaming and ICT industries, as well as "help passionate gamers around the world exchange information and build friendships" (Sung-Jin, 2001 in Taylor, 2012, p. 22).

Brazil, on the other hand, does not have the same level of unity among the agents that make up the national esports landscape. However, this has not prevented some attempts at institutionalization over the years. The "Confederação Brasileira do Desporto Eletrônico" v (CBDEL) and the "Confederação Brasileira de Games e Esports (CBGE)vi, for example, are some initiatives trying to establish themselves as official representatives and national entities administering esports, although their positions are widely contested by the country's main developers and teams (Falcão et al., 2023). Still, both organizations are private and nonprofit entities and display the national certification of the Ministry of Citizenship, represented by the Special Secretariat for Sports and the Secretariat of High Performance Sports, as the administrators of Brazilian sports.

However, the main esports teams and organizers in Brazil do not recognize the legitimacy or competence of CBDEL, CBGE, or any other national entity to regulate or oversee the practices of this modality in the country. By observing the response letter from the Brazilian Esports Ecosystem to Bill 383/2017 (Falcão et al., 2023), one of the first attempts at regulation by the State, as well as controversial cases involving disagreements between these actors and CBDEL, it is possible to observe the discrediting of these organizations by such agents.

In addition, the speech of Brazil's former Minister of Sports, Ana Moser, in an interview with the UOL news portal in January 2023, reveals a contradictory institutional view in the country regarding the legitimacy of digital games as a sports practice. At the time, she commented on the exclusion of esports from the definition of sports in the "Plano Nacional do Desporto (PND)vii". In her statements, the Minister said:

> *"The text [of PND] is there protecting the true sport. In the definition of sport an opening had been given that could include electronic sports, and we closed this definition to not take that risk. [...] In my opinion, electronic sports is an Entertainment industry, it is not sport" (Moser in UOL Esporte, 2023, on-line, translated by the authors).*[viii]

Although the argument that esports are a form of entertainment is not entirely incorrect, the activity is not limited to this aspect. There is a consensus in game studies that understands esports as both sports products and entertainment media, resulting from a process of rulemaking and discipline within digital games (Jin, 2010, 2021; Macedo, 2023b; Taylor, 2018; Wohn & Freeman, 2020). The interpretation put forth by the former minister, therefore, restricts the understanding of esports as a holistic and multidimensional media ecosystem (Macedo, 2023a; Wohn & Freeman, 2020).

During that same occasion, the former minister generated discontent within the Brazilian gaming community by stating that she does not consider esports to be a sports modality, comparing the preparation of a video game athlete for a competition to that of an artist for a performance. By affirming that she did not intend to direct investments toward the sector, Ana Moser contributed to the perpetuation of an institutional perspective that increasingly distances Brazil from the debate on public policies and investments in esports.

6.2. Regulation

The years 2006 and 2012 marked significant advancements in legislation surrounding esports in South Korea. The Game Industry Promotion Act (2006) and, most notably, the Act on Promotion of E-Sports (2012) formalized various obligations of the South Korean government regarding the emerging industry. The latter consists of 18 articles covering topics ranging from the responsibilities of the federal and local governments in relation to esports and their promotion (Articles 4 and 5) to the conditions for funding and the professionalization of qualified personnel (Articles 8 and 10), making it a comprehensive legislative tool to prevent legal issues in the following years.

Furthermore, the Act on Promotion of E-Sports, as well as Article 10 of the Game Industry Promotion Act, establishes the South Korean government's interest in fostering and encouraging the competitiveness of South Korean esports on the international stage, as well as promoting exchanges with other countries, as stated in the following excerpt:

> *“Article 14 (Assistance in International Exchange and Overseas Publicity) (1) In order to invigorate international exchanges of e-sports, the Government may provide necessary assistance to the following institutions: 1. The International e-Sports Federation; 2. An institution or organization, the capital of which is partially funded by the Government. [...]. (2) In order to enhance the competitiveness of domestic e-sports and invigorate the expansion of overseas markets, the Government may implement programs for overseas publicity.” (Act on Promotion of E-Sports, 2012).*

This article highlights the government's intention to use esports as an international publicity tool to secure benefits such as the expansion and strengthening of the sector in foreign markets, effectively constituting a South Korean foreign policy measure through esports.

In the Brazilian context, on the other hand, there have been some attempts by the state to regulate the practice. One notable example is Senate Bill (PL) No. 383/2017, introduced by Senator Roberto Rocha from the Partido Social Democrata Brasileiro[ix] (PSDB / State of Maranhão), which aimed to regulate esports activities in Brazil. The proposal, led by CBDEL in an attempt to take over the administration of esports in the country, was inspired by the General Sports Law (Law No. 9,615/98), popularly known as the "Pelé Law"[x], and sought to grant professional esports players the same status

as athletes. Additionally, it recognized esports as a democratic and universal activity, serving as an initial step toward potential government support for players.

After strong opposition from various stakeholders in the Brazilian esports scene—including players, influencers, pro-players, and game developers (Falcão et al., 2023)—the legislative process of PL 383/2017 was ultimately shelved after six years, with only two public hearings held. Given the bill's failure, federal units decided to act independently. Between 2019 and 2022, eight states and one Brazilian capital enacted ordinary laws to regulate esports, including Alagoas (Law No. 8.219, 2019.), Amazonas (Law No. 5.321, 2020), Bahia (Law No. 14.116, 2019), Espírito Santo (Law No. 11.515, 2021), Goiás (Law No. 21.080, 2021), João Pessoa (Law No. 14.385, 2022), Mato Grosso (Law No. 11.830, 2022), Paraná (Law No. 20.281, 2020), and Santa Catarina (Law No. 18.396, 2022)[xi]. The content of these laws closely resembles PL 383/2017, equating pro-player status with that of athletes and paving the way for public administration support. However, some federal units went further, such as Mato Grosso, which assigned the state the responsibility of organizing competitions and granting credits and benefits to players (Law No. 11.830, 2022).

Moreover, another bill (PL 70/2022) revives the text of PL 383/2017, reintroducing a legislative proposal very similar to its predecessor. Currently, this bill has been under review in the Brazilian Chamber of Deputies for over two years. Due to uncertainties and the lack of regulatory unification from the Brazilian government on the matter, potential investments and the organization of a domestic professional esports ecosystem remain hindered. Despite state and municipal laws, the industry is still largely led by game developers and private corporations, which manage the country's largest and most significant esports competitions and regulate relationships among the various stakeholders across different disciplines.

6.3. Economic Integration

One of the key characteristics observed in the global esports sector is the continuous rise in the number of multinational and transnational organizations investing in the market. In South Korea, domestic companies frequently invest billions of wonxii in team development and infrastructure to compete in the country's largest tournaments. Some of the major companies involved include Nongshim Co Ltd, SK Telecom Co Ltd, Hyundai Motor Co, Kia Corp, Hanwha Life Insurance, and KT Corp. Despite the relatively low volume of formal government subsidies for the gaming and esports industry — accounting for only 0.11% of the country's annual budget in 2021 (Roh, 2021) — capital from multinational corporations and game developers serves as the primary financial driver of South Korea’s esports scene.

Similarly, in 2015, KeSPA announced a partnership agreement with L.ACE to regulate and facilitate the transfer of esports pro-players between South Korea and China (Vanese, 2015). Since both nations are strong competitors in the industry, many top-tier professionals are exported to other regions of the world to compete on international teams, including in Brazil (Oliveira, 2023). As a result, this unprecedented cooperation agreement opens new opportunities for the relationship between the two countries in this market.

In South Korea, certain esports titles with high popularity, such as League of Legends (LoL), serve as ideal environments for developing athletes who later compete internationally. At least one South Korean professional can be found participating in official LoL tournaments on every continent. For example, in 2023, Brazil had 13 South Korean professionals working in the scene, either as players or as coaches (Oliveira, 2023). This phenomenon is not observed to the same extent with Brazilian athletes in mainstream esports titles.

The Brazilian market has also seen multimillion-dollar investments from corporate conglomerates, often involving both national and international companies. One notable example is the creation of the Spacecaps group, formed by LOUD, one of Brazil's largest esports organizations, alongside six other companies—five of which are based in North America. Despite the lack of formal government investments in Brazilian esports, the industry's development by private entities has successfully attracted significant foreign investments. In 2018, Team Liquid — the world's third-largest esports organization — and in 2021, Team SoloMid (TSM) — the largest esports organization in the world — funded Brazilian teams in emerging esports titles, including Rainbow Six Siege, Free Fire, Wild Rift, and female Valorant.

6.4. International Advertising Strategies

Digital games are dispersed in everyday life, not only in an explicit manner but also subtly through streaming services or the growing dependence on games as part of transmedia storytelling. As a byproduct of the digital gaming industry, esports often take on an ambiguous role in terms of its classification as an industry. In the local context, the "Korean Wave" was driven by the national government, with elements of popular culture becoming a crucial resource for South Korea's diplomacy. The state then moved forward with the articulation of public policies aimed at cultural diplomacy as an essential component of its foreign policy (Nye & Kim, 2019). As a result, the digital gaming industry, and specifically esports, became part of the South Korean government's portfolio for developing public policies to promote its gaming culture abroad. This is highlighted by the acts already presented in the Regulation section.

Additionally, it is a worthy mention the fact that many giant private corporations in South Korea are using famous national esports players as brand ambassadors. Technology brands like Razer, for example, are associating their products with athletes like Faker, the most famous League of Legends player worldwide. Even though this is not a South Korean foreign policy strategy, it still advertise South Korean esports actors as synonyms of quality and good performance.

In the Brazilian diplomatic scene, on the other hand, digital games are a recent topic within the Ministério das Relações Exteriores (MRE)[xiii]. In December 2022, MRE published the "Panorama Internacional de Mercados de Jogos Eletrônicos" (International Overview of Electronic Games Markets). In the document, the institution highlights the potential of the gaming market both in Brazil and abroad, but with an emphasis on game developers (Ministério das Relações Exteriores, 2022). Therefore, esports have not yet been included in Brazil's cultural diplomacy efforts, but the creation of the report suggests a possible future engagement with the topic.

6.5. Public Prestige

The international success of a player or national team, as well as the successful hosting of a mega sports event, provides arenas for a country to gain international leverage (Haut et al., 2017). Roche (2003) presents the concept of mega-sporting events as temporary cultural actions that have long-lasting pre- and post-event social dimensions. The public perceives these events as extraordinary occurrences due to their large scale, the time intervals between their editions, and the impacts they generate.

With this in mind, we conducted a survey of the largest international competitions of 10 out of the 14 most-watched games in 2022, according to the Esports Charts portal (2022)[xiv]. The goal was to assess how many times Brazilian and South Korean players or teams appeared on the podium of each game's largest international tournament, as well as how many times the countries hosted such high-profile events. The criteria for selecting the 10 games were: the number of viewers (audience size); presence of the game in Brazil and South Korea; the competitive nature of the game; and the clear nationality of the teams. The latter criterion, in particular, made Fortnite unsuitable for analysis, as its main world tournament (Fortnite Champion Series) is played only in duos, and its scoring and nationality dynamics are difficult to analyze. Moreover, no Brazilian or South Korean representatives were present in this competition. Thus, the following tournaments were selected, divided into three genres:

Table 2: Tournaments selected to the analysis by game genre

Game Genre	Analyzed Tournaments
Multiplayer Online Battle Arena (MOBA)	League of Legends World Championship (2011 – 2023), Mobile Legends: Bang Bang M World Championship (2019 – 2022), Dota 2 The International (2011 – 2022), Arena of Valor World Cup (2018 – 2021) and Brawl Stars World Finals (2019 – 2023).
First Person Shooter (FPS)	CS:GO Major Championships (2013 – 2023), Valorant Champions Tour (2021 – 2023) and Overwatch World Cup (2016 – 2019).
Battle Royale	PUBG Mobile Global Championship (2020 – 2023) and Apex Legends Global Series (2022).

The data about these competitions were gathered from Liquipedia, an esports wiki that stores real-time data on tournaments, players, teams, and matches from a myriad of competitions[xv]. The choice of Liquipedia is justified by the reliability that the portal has within many esports actors, as well as by its role as a tool that consolidates precise data on the history of the world's major esports competitions. Table 3 illustrates the survey results, emphasizing the number of appearances by each country per game genre and the number of events hosted by each nation within the analyzed competitions.

Table 3: Frequency of Hosting and Podium Appearances by South Korea and Brazil in the Major International Esports Competitions by Genre until March 2023

Genre/Place	1st Place	2nd Place	3rd Place	Total	Hosted Events
MOBA – South Korea	8	6	7	21	2
MOBA – Brazil	0	1	1	2	0
FPS – South Korea	4	0	2	6	0
FPS – Brazil	3	3	5	11	2
Battle Royale – South Korea	0	0	0	0	0
Battle Royale – Brazil	0	1	1	2	0

It is observed that the total number of podium appearances by South Korea (27) in the analyzed events is 80% higher than Brazil's appearances (15). South Koreans show superior results only in the MOBA genre, with a highlight for the LoL (League of Legends) modality (20 appearances). On the other hand, Brazil has a greater presence on the podiums in the FPS and Battle Royale categories, with highlights in CS:GO (8 appearances) and Valorant (3 appearances). Regarding the hosted events, both Brazil and South Korea organized two events, but in game genres that represent their best international performance. This suggests that a country with greater prestige in a particular genre is also more likely to be selected as the host for mega esports events in that same genre, as indicated by research on the limitations of public prestige in sports by Haut et al. (2017). Our survey considered only teams formed by at least three players of Brazilian or South Korean nationality or teams operating under an organization founded in one of these two countries.

6.6. Summary of Results

Table 4: Comparison of the Analyzed Variables between South Korea and Brazil.

Analyzed Variables	South Korea	Brazil
Institutionalization	It has KeSPA, nationally recognized by the ecosystem's actors. With the support of the Ministry Of Culture, Sports and Tourism, it regulates esports.	It has CBDEL and CBGE, entities certified by the Ministry of Citizenship, but not recognized by game developers or the esports community as regulators of the practice
Regulation	It has, at the national level, the Act on Promotion of E-sports.	It does not have a nationally approved law that regulates esports.
Economic Integration	It has public-private cooperation and investment initiatives in the sector, with a focus on professional esports.	Private, community, and university initiatives predominate in the economic relations of Brazilian esports.
International Advertising Strategies	Esports are incorporated into the South Korean *Hallyu* as an area to be promoted by the country's cultural diplomacy, carried out by the Ministry of Culture, Sports and Tourism.	It does not have formal measures from the Ministry of Foreign Affairs regarding esports.
Public Prestige	It has International prominence in the MOBA game genre.	It has international prominence in the FPS and battle royale game genres.

The analysis of the development of public policies aimed at the international projection of Brazil and South Korea – through esports – requires a multifaceted approach. Part of this is due to the

complexity involved in shaping a state's foreign policy agenda. Additionally, the intersectionality in games, generally, and in esports, specifically, makes it difficult to analyze from a single perspective. Therefore, Table 4 briefly presents the responses obtained from each of the fields analyzed in this study, in order to make a direct comparison between the two investigated scenarios.

It is observed that South Korea has institutions, laws, and cultural diplomacy initiatives involving esports, being considered a pioneer in this type of policy (Jin, 2010). Therefore, absolute gains in foreign policy can be seen in the areas of alliances and partnerships, economic integration, and the country's public prestige in the international arena (Pinto, 2011). When observing these data, it is possible to reach the conclusion that South Korea has a more established approach – especially with its public institutions – regarding the field of esports. We believe in the possibility that, beyond the absolute gains earned by the country with its esports scenario (international prestige, economic integration, agreements and trade opportunities – to say the least), part of its strong esports culture[xvi] has its basis in these set of policies and strategies.

Brazil has a less established formalized scenario. The lack of a widely recognized regulatory institution among internal actors, as well as the absence of national-level regulation of the practice, hinders the establishment of economic integration initiatives and the inclusion of the topic in the cultural diplomacy portfolios of MRE. Nevertheless, the country has achieved remarkable results in certain genres, despite the absence of state action, which represents an international gain in public prestige within the esports community, particularly in the FPS and battle royale genres.

These achievements, however, are frequently the results of much effort from the players (Macedo, 2023b). As Brazil do not have a unified approach to internally support its esports scenario, and consequently has minor international gains with it, national players' journey towards professional success is much harder. It does not mean, notwithstanding, that some players achieve status of celebrities, like Gabriel 'Fallen' Toledo, or Felipe 'brTT' Gonçalves. But, even in their cases, remuneration is still far away from the South Korean pros[xvii].

8. Final Considerations

In this paper, we present an exploratory comparative study of the existing public policies in Brazil and South Korea, aimed at both fostering and improving esports practices within their territories and obtaining international gains through success in these practices. By gathering information from institutional websites of both countries, a comparative case study was conducted to identify the existence and initial framework of public policies related to esports in both nations. During the data collection process, 50 results related to the topic were identified, with 29 referring to Brazil and 21 referring to South Korea, distributed among articles, laws, bills, and decrees. Bibliography on the subject was also consulted in order to understand local cultural aspects regarding the practice of esports, and concepts of cultural diplomacy applied to foreign policy, and its connection with sports. Through qualitative analysis of all the material, it was possible to understand the general treatment of the phenomenon within each country's political-administrative reality.

Among the main findings, the robust vision developed by the South Korean government regarding the phenomenon and its direction of esports as part of a sophisticated cultural diplomacy strategy stands out. In the Brazilian context, an uncertainty within the national government regarding esports was identified, which serves as an obstacle to the development of public policies to promote the practice and, consequently, the assignment of the topic within the Ministry of Foreign Affairs' cultural diplomacy portfolio.

Research in International Relations analyzing esports as a tool of foreign policy is scarce, and the subject is still very recent in academia. However, the flow of information on the topic is constantly renewed, making it necessary to update research on the phenomenon. Therefore, we believe that developing new studies on esports policies is important for the maturation of the understanding regarding the connections between cultural diplomacy, soft power policies and different esports modalities, especially in the reality of other countries that excel in the field[xviii].

This research also has limitations, primarily related to language barriers. Therefore, it is important for the reader to be aware of the scope of the repositories and languages examined, as well as the period of the materials consulted, as the research data were majorly collected up until March 2023. In addition, as other possible limitation of this study, we only used secondary data in our analysis. We strongly recommend future studies to explore primary sources, conducting interviews or other forms of direct contact with important actors such as pro-players, regulatory institutions' members, sponsors and policymakers.

The points presented here aim to highlight some exploratory reflections that may support a discussion between the fields of game studies, Communication, and International Relations. This, in turn, suggests future projects that may explore this argument in different game genres like MMOs or Card Games, for example. These questions, however, may contribute to the creation of an agenda of tension and debate that seeks to address the complex relationships between esports, foreign policy, and cultural diplomacy, as three key axes of articulation in interface with the universe of esports, Communication, and the field of International Relations.

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[i] Foreign Policy here refers to the strategies adopted by a country to pursuit their interests outside its borders. Discussion regarding this concept is in "Foreign Policy and National Interests section (p. 3).

[ii] Discussion regarding this concept is also in "Foreign Policy and National Interests section (p. 3).

[iii] A good example of this can be observed in international programs such as "Experience Africa". Created by the Institute for Cultural Diplomacy, the initiative brings together students and young professionals from across the African continent, and the wider international community, to learn more about political, economic and cultural issues of the African continent. During the reunion, participants have the opportunity to expand their vision about the continent and change the stereotyped vision of poverty that is commonly associated with Africa.

[iv] Our goal in this article is not to dwell on the sociological definition of esports and its relation with traditional sports. Not because this is trivial – which is not –, but because it would render a large discussion that was already competently conducted by sports sociologists (Jonasson; Thiborg, 2010), and adapted to the context of the Global South (Macedo, 2023b).

[v] Brazilian Confederation of Electronic Sports (free translation)

[vi] Brazilian Confederation of Games and Esports (free translation)

[vii] National Sports Plan (free translation)

[viii] Original (portuguese): "O texto [do PND] está lá protegendo o esporte raiz. Na definição de esporte tinha sido dado uma abertura que poderia incluir esporte eletrônico, e a gente fechou essa definição para não correr esse risco. [...] A meu ver, o esporte eletrônico é uma indústria de entretenimento, não é esporte".

[ix] Brazilian Social Democracy Party (free translation)

[x] It is the legislation that establishes the general rules for sports in Brazil, regulating areas such as athlete contracts, club management, and transfers.

[xi] In addition to these, the states of Ceará and São Paulo also introduced similar legislative proposals. However, their progress was halted due to different controversies. In Ceará, a conflict of interest among legislators led to the bill's shelving. In São Paulo, the state government declared the proposal unconstitutional, arguing that it was impossible to regulate an entity protected by intellectual property rights. It is worth noting that São Paulo, the state capital, hosts the majority of esports organizations' offices in Brazil, including the headquarters of the country's main teams and national competitions.

[xii] The national currency of South Korea. On March 9, 2023, **R$1.00** was equivalent to **256.70 won**.

[xiii] Ministry of Foreign Affairs (free translation)

[xiv] The choice of this specific portal was because it organizes the most-watched games of 2022 by peak viewership (the number of people watching simultaneously). In practice, the highest viewership peaks for competitive games occur during the finals of international megaevents. Thus, it is possible to extract which games had the most viewership precisely during these events. Available at: https://escharts.com/top-games?order=peak&year=2022. Accessed on Feb. 09, 2025.

[xv] An online encyclopedia where users themselves contribute by adding or correcting data. Available at: https://liquipedia.net. Accessed on Feb. 09, 2025.

[xvi] Although not properly discussed in this work, South Korea was the first country to have a TV channel dedicated to the streaming of esports content – OnGameNet (OGN), already in 1999. Many of their esports pro-players are treated as big celebrities, receiving a lot of gifts and donations by fans and moving a crowd of people where they are (Jin, 2010).

[xvii] According to the portal Esports Earnings (2025a, 2025b, 2025c), just with tournament prizes, brTT and Fallen received a little more than 1.3 million US dollars in 228 tournaments, while Lee "Faker" Sang Hyeok gathered more than 1.8 million US dollars just with 72 tournaments. This value is not considering other sources of income, such as livestreaming, donations and sponsorships. It illustrates the huge difference in the financial prize of national tournaments (the majority in both their lists), considerably higher in South Korea.

[xviii] We refer to countries like the United States, China, Japan, France, Germany, Italy, Vietnam, Russia, and many others where esports is a successful practice.

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Low-cost mobile 3D scanning of heritage objects to facilitate long-distance research collaboration - a technical note

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Abstract
While three-dimensional visualization has become a common tool in various cultural heritage applications, the emphasis has been on high fidelity representation, essentially the generation of digital twins or digital reconstructions. Overlooked appears to be the utility of 3D in research collaboration where one of the researchers has access to the original, potentially fragile object while the others are based in remote locations. This technical note describes the application of a low-cost, mobile and swiftly executable 3D scanning process and discusses the benefits of this for remote collaboration of three-dimensional objects of material culture.

Keywords 3D models; low-cost solutions; collaborative research; material culture; pottery; souvenir ware

1. Introduction

Three-dimensional visualization has become a common tool for the representation of cultural heritage objects in museum settings (Luther, Baloian, Biella, & Sacher, 2023), to create interactive, web based virtual museums (Carvajal, Morita, & Bilmes, 2020; Sillaurren & Aguirrezabal, 2012; Zidianakis et al., 2021), to generate 'digital twins' (Qian et al., 2022) for heritage interpretation (Dezen-Kempter, Mezencio, Miranda, De Sãi, & Dias, 2020), but also specifically to create visualizations in case of destruction during natural disasters or armed conflict (Hou, Lai, Wu, & Wang, 2024; Shabani et al., 2022; Vuoto, Funari, & Lourenço, 2023, 2024), as well as gaming environments representing historic settings (Champion, 2016; Ishar, Zlatanova, & Roberts, 2022; Kargas, Loumos, & Varoutas, 2019). These 3D models may be static but are more commonly animated. Some of these visualizations represent the objects as they are (Girelli, Tini, D'apuzzo, & Bitelli, 2020), while others represent reconstructions of earlier, pre-modification, pre-decay or pre-disaster states (Martinez Espejo Zaragoza, Caroti, & Piemonte, 2021). Given the desired quality of output, these approaches commonly require photogrammetric equipment (for larger sites) or laboratory-/studio-based set ups with controlled lighting and camera/recording positions.

Despite the plethora of papers discussing actual and possible uses of 3D models in cultural heritage studies, there appears to be no mention of their use in research collaboration. The aim of this

brief technical note is to describe a low-cost, mobile 3D scanning process used to represent three-dimensional objects of material culture for collaborative research by researchers separated by large distances and discusses the benefits of 3D models for remote collaboration.

1.1. Background

The authors are generally interested in the attitudes of the dominant Australian community of the 1950s and 1960s towards Indigenous Australian peoples and how a then essentially a settler-colonialist mindset manifested itself in the stereotyping of appearances of Indigenous Australian peoples and in the appropriation of Indigenous Australian motifs on objects of post-World War II material culture (Spennemann, 2022; Spennemann & Hurford, 2025; Spennemann & Singh, 2023). One of the prominent examples are small slip-cast ceramic pieces (‘pin dishes’) created by Vandé pottery (Sydney) that exhibit the heads of Indigenous Australian men in relief. In the preparation of an academic manuscript discussing these pin dishes, it was essential for both authors to be able to examine, analyze and discuss these pieces and in particular the ‘physiognomy’ of the relief heads. This was, however, encumbered by the fact that the authors reside on different campuses of the same academic institution spaced 450˚km apart. An appropriate solution was considered to be the generation of 3D models.

1.2. Requirements

For the purposes of the research collaboration there was no need to develop high-quality but time-consuming models suitable for external presentation and public consumption as these models were to be solely used for internal discussion. The requirements were that the process

- had to be low cost
- could be executed with personally available technology,
- was easy to learn,
- could be implemented in a non-laboratory setting, and
- was not time consuming to execute

2. Technique

The plates were scanned using the rear camera of one of the author’s (DHRS) standard personal Samsung S21 Android smartphone and converted into a 3D model with the KiriEngine Application (free version) with server-based processing (KIRI Innovation, 2024b). The process entailed to place the plate on a table in ambient daylight and to take 100 sequential images of the object with the KiriEngine Application (which draws on the camera’s 12 megapixel setting). As the focus was on the relief heads of the pottery, the backside of each plate was irrelevant and thus not scanned. The application uploads the images to the vendor’s servers, where they are queued for processing. The application window needs to remain open and in the foreground during the upload process, the duration of which is subject to network speed and server responsiveness. Once the upload is

completed, the user regains full access to all smart phone functions without impact on the model. Once processing is complete, the 3D model will reside on the KiriEngine server (until user deleted) and can be viewed both within the smartphone application itself or on any web browser using a shared weblink.

While not necessary for the functionality required for the collaborative research, the authors chose to 'tidy up' the scans by removing egregious excess areas (i.e. parts of the table-top included in the scan when moving the camera). The trimming entailed to interactively move a cropping slider to the required position and to save that crop as a new version—and to repeat the process until all four sides had been cropped resulting in the plate residing on a rectangular 'base'. A copy of the final plate model was then further cropped to isolate the head.

None of the image generation processes require operator intervention and therefore can run in the background. Sound feedback alerts the user once the model processing (initial generation or trimmed models) is complete.

3. Results

For the project, five plates, representing different molds, were scanned and processed on 4 December 2024 (Appendix A). For this paper, an additional five plates were scanned and processed (7 and 8 December), noting the required time for image acquisition, uploading, processing and final cropping (Appendix B). The recorded times are indicative only as they depend on the efficiency of the operator (image acquisition, adjusting cropping boundaries), network connections (upload speeds) and server load (remote processing). The impact of the server load, for example, is exemplified by the remotely executed processing and saving of a cropped 3D model which took between 41 and 9 minutes 9 seconds (average 5 minutes 13 seconds, n=16). Differential load on the KiriEngine server, which can only process 12 scans at any given time (KIRI Innovation, 2024a), also impacted the generation of the original model which ranged from 11 minutes 52 seconds to 49 minutes (Table 1).

Table 1: Time investment in the key phases of 3D model generation

	Average	Min–Max
Image acquisition	03:11±00:21	02:45–03:38
Upload	12:16±05:12	07:52–19:52
Processing	27:46±17:30	13:50–49:00
Cropping to Plate	19:28±09:34	05:21–30:38
Cropping to Head	18:03±09:34	04:34–29:02
File renaming / deletion	00:13±00:02	00:10–00:15
Total	1h20:46±18:27	1h 01:24–1h 47:38

The completed models reside on the KiriEngine server and can be accessed via server-assigned URLs (Appendix A). In addition, the application allows for download of 3D model data for external archiving. The models used for the main study (Spennemann & Hurford, subm.) as well as this paper have been archived in the research repository of the authors' institution (see data availability).

A B

C B

Figure 1. Screen shots of two 3D models of Vandé pin dishes generated for the project. A, B) plate A2-7 (whole plate); C, D) plate B1 (head section only).

4. Discussion

As noted, the purpose of the 3D scanning was *not* to create high-quality models for presentation, but to rapidly and comparatively effortlessly generate 3D models that could be repeatedly viewed by a second, remotely located researcher. The direct benefits of the approach were that the images could be generated using personally available (extant) smartphone technology in a non-laboratory setting and that the generation of the models was not time consuming. Server-based access to the 3D model meant that the second author could manipulate the object virtually, thus obviating inter-campus travel with its costs, effort, travel time and carbon footprint. Additionally, it reduced the need for repeated handling of the original, potentially fragile objects, which also applied to the first author. This greatly facilitated research and manuscript completion (Spennemann & Hurford, subm.).

An unanticipated benefit of the 3D model was that the images were rendered without the gloss of the ceramic glaze. While this would be considered a 'fault' in 3D models used for formal public representation, it allowed to examine the 'physiognomy' of the heads without the distracting reflections that the glaze generated on the dark colored faces of the originals.

A potential short-coming of the approach is the lack of haptic (texture, heft) and olfactory feedback (smells) that form an important part of the ontological qualities of material culture and where its absence may diminish the experience. In the specific case described here, that was of no concern as glazed pottery is odorless and does not offer differential textures. The weight/heft of the specimens was also irrelevant in our case.

The ease of use with personally available smartphone technology will allow a researcher to scan an object in a private collection or field setting, where removal is ethically, legally or physically impossible. Moreover, it allows the researcher to share the image with remotely located collaborating researchers who, after manipulation of the 3D model, can instruct the researcher in the field to make additional observations if required. This generates a higher level of collaborative potential than looking at objects via Facetime, Zoom or similar technologies.

While our primary motivation related to research collaboration, these 3D models can also be generated 'on the fly' to be used in online tutorials to demonstrate certain aspects, allowing students to independently look at the examples as well.

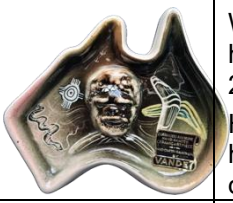
5. Conclusions

The low-cost example described in this technical note can be used anywhere as long as a network connection can be accessed via WiFi or a mobile/cell phone network to upload the images. All subsequent processes can occur asynchronously. If the need arises, a series of images can be taken and uploaded and processed at a later point in time. Once uploaded and (automatically) processed, the images are located on the server and can be readily accessed and interactively manipulated anywhere in the world via a shared URL. The low-cost nature with widely owned technology (i.e. a camera-equipped smartphone) and internet access, as well as a mobility independent of fixed laboratory set-ups, makes the technology eminently suitable for the collection and dissemination of workable 3D models of items of material culture as encountered in small museums, private collections, or the field, where removal is ethically, legally or physically impossible.

Appendix A: Server-based 3D models generated for the project

Three-dimensional models were generated for the following ten plates. The URLs point to the models residing on the Kiri Engine server. All links accessed on 8 December 2024.

ID	Plate	URL
A1-1		Whole plate: https://www.kiriengine.app/share/ShareModel?code=W2ZK8I&serialize=31ecdf591301459bb4b072214db7ce85 Head only: https://www.kiriengine.app/share/ShareModel?code=W2ZK8I&serialize=275f4f9fd5f246738a4efa4421a2b037
A1-2		Whole plate: https://www.kiriengine.app/share/ShareModel?code=W2ZK8I&serialize=0791880070c1425ca45d42c52f973bc9 Head only: https://www.kiriengine.app/share/ShareModel?code=W2ZK8I&serialize=4b260ae4e2394b85b3b6ec662ae53286
A2-6		Whole plate: https://www.kiriengine.app/share/ShareModel?code=W2ZK8I&serialize=927df77134674f0a992cf1b54c0edf75 Head only: https://www.kiriengine.app/share/ShareModel?code=W2ZK8I&serialize=e84e1ff34b8446229a3af99b7b189475
A2-7		Whole plate: https://www.kiriengine.app/share/ShareModel?code=W2ZK8I&serialize=5773c8ebb9e64fa5b06b38834eda00fb Head only: https://www.kiriengine.app/share/ShareModel?code=W2ZK8I&serialize=cf2ec43fedec4cd6a1b769062071085b
A2–13		Whole plate: https://www.kiriengine.app/share/ShareModel?code=W2ZK8I&serialize=9355474fa5a749918df19e4c18f555a3 Head only: https://www.kiriengine.app/share/ShareModel?code=W2ZK8I&serialize=632d60500ab04e489102471740225a67
A2-16		Whole plate: https://www.kiriengine.app/share/ShareModel?code=W2ZK8I&serialize=6ab90e2cdde6421b932782ff7b894d80 Head only: https://www.kiriengine.app/share/ShareModel?code=W2ZK8I&serialize=977e0289fdb74b829cdaa1ad9e0ad9c6
B1		Whole plate: https://www.kiriengine.app/share/ShareModel?code=W2ZK8I&serialize=ce761ec4f27e4db3813535c93d322b11 Head only: https://www.kiriengine.app/share/ShareModel?code=W2ZK8I&serialize=958ce9ed33aa45d3afdda41a92de007d

ID	Plate	URL
B6		Whole plate: https://www.kiriengine.app/share/ShareModel?code=W2ZK8I&serialize=6582b4a7aa5a4fe5b967e7a65fb25661 Head only: https://www.kiriengine.app/share/ShareModel?code=W2ZK8I&serialize=632d60500ab04e489102471740225a67
D1		Whole plate: https://www.kiriengine.app/share/ShareModel?code=W2ZK8I&serialize=903f0caaac9248139000e3a2dbd85c84 Head only: https://www.kiriengine.app/share/ShareModel?code=W2ZK8I&serialize=f5c9d87dabe643deb57514e0031db523
D2		Whole plate: https://www.kiriengine.app/share/ShareModel?code=W2ZK8I&serialize=c20c35882d434d869ab2f41d6b834433 Head only: https://www.kiriengine.app/share/ShareModel?code=W2ZK8I&serialize=a0aa6313633d42fa9e878517a7c03e04

Appendix B: Time taken for various model development steps (hh:mm:ss)

	A1-2	A2-6	D1	B6	A2-13
Image acquisition					
Photography	00:03:09	00:02:45	00:03:38	00:02:59	00:03:23
Processing					
Upload	00:19:52 *)	00:15:26 **)	00:08:18	00:09:54	00:07:52
Queueing	00:00:00	00:02:05	00:03:23	00:00:56	00:00:14
Remote Model Processing	00:49:00	00:11:52	00:14:06	00:12:54	00:44:20
Total time to useable model	01:12:01	00:32:08	00:29:25	00:26:43	00:55:49
Crop to plate margin					
manual adjustment side 1	00:00:23	00:00:27	00:00:20	00:00:23	00:00:21
Processing side 1	00:01:45	00:01:05	00:06:38	00:09:13	00:01:09
manual adjustment side 2	00:00:32	00:00:21	00:00:23	00:00:25	00:00:26
Processing side 2	00:01:39	00:06:52	00:10:23	00:06:58	00:01:19
manual adjustment side 3	00:00:26	00:00:20	—	00:00:22	00:00:19
Processing side 3	00:07:05	00:09:09	—	00:06:52	00:00:45
manual adjustment side 4	00:00:34	00:00:21	—	00:00:31	00:00:25
Processing side 4	00:05:40	00:06:57	—	00:05:54	00:00:37
Crop to head margin					
manual adjustment side 1	00:00:20	00:00:22	00:00:18	00:00:15	00:00:19
Processing side 1	00:08:21	00:05:27	00:02:02	00:05:49	00:01:05
manual adjustment side 2	00:00:22	00:00:27	00:00:24	00:00:27	00:00:16
Processing side 2	00:00:41	00:06:27	00:09:04	00:08:38	00:00:45
manual adjustment side 3	00:00:21	00:00:30	00:00:24	00:00:27	00:00:20
Processing side 3	00:00:53	00:06:44	00:00:58	00:08:55	00:00:45
manual adjustment side 4	00:00:24	00:00:26	00:00:21	00:00:31	00:00:19
Processing side 4	00:05:59	00:08:39	00:00:44	00:06;40	00:00:45
file renaming and deletion of superfluous files	00:00:12	00:00:10	00:00:12	00:00:14	00:00:15
Total time	01:47:38	01:26:52	01:01:36	01:22:37	01:05:59

*) Wifi to Broadband, 12.77 mbps upload; **) phone upload to 5G cell phone network;

Author Contributions: Conceptualization DHRS; Methodology DHRS; Data Curation DHRS; Formal Analysis DHRS; Writing – Original Draft Preparation DHRS; Writing – Review & Editing DHRS & SH; Visualization DHRS.

Data availability: The data can be accessed from authors' institutional research depository via this URL: https://doi.org/10.26189/d0d4ab7a-4003-4d45-92fb-6976c2f5096d.

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