MAR AS A BRIDGE BETWEEN HISTORICAL NARRATIVES AND ARCHITECTURAL SPACES

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ABSTRACT

Architectural visualisation is important as it defines how people experience the built and natural environment through their visual senses. Over time, it has evolved from traditional 2D line drawings to computer-generated 3D models and virtual reality environments [5]. Among emerging technologies, augmented reality (AR) has proven to be an effective tool for making architectural visualisations more immersive and experiential. AR seamlessly integrates visual, auditory, and haptic elements into the real world, enabling users to interactively explore architectural spaces and historical narratives in real-time. This research investigates the transformative potential of augmented reality (AR) in preserving and interpreting architectural heritage, focusing on the events in the Finnish Civil War around Näsilinna Castle. Various AR tools exist, including headsets, glasses, and mobile devices, but mobile AR was chosen as a low-threshold, accessible solution for enhancing public engagement with cultural heritage. The mobile AR application developed in this study allows users to virtually explore historical artefacts and the castle's wartime architecture, overlaying augmented models onto real-world environments. This interactive approach deepens user engagement with historical narratives, enabling them to manipulate artefacts and architectural elements without compromising the safety of physical artefacts preserved in museums. By integrating multiple historical perspectives and architectural narratives, this AR application offers a new way to interact with heritage, shifting users from passive observers to active participants. Unlike traditional heritage preservation methods, AR enables users to experience historical transformations firsthand. Given the innovative and evolving nature of this research, the "Research through Design" (RtD) methodology was adopted, allowing for iterative testing and refinement to generate new insights. Lastly, this study contributes to exploring the role of augmented reality in architectural heritage preservation, highlighting its potential to explore another perspective on how we engage with and interpret spaces.

KEYWORDS: Architectural Heritage Preservation, Augmented Reality (AR), Research Through Design (Rtd).

1. INTRODUCTION

The built environment has been one of the main anthropic spaces for at least ten thousands years. It is a multilayered environment, where new layers of architectural constructions are added to existing ones, creating spaces, like cities, where elements from different historical eras coexist and are in constant semantic dialogue with each other. To the many historical physical layers existing in urban spaces, technological development has added a series of digital ones, that range from digital, mapping, and smart city technologies [17, 22] to Extended Reality Technologies (XR). The compresence of these different layers opens up to many potential interactions between them, in terms of integration of digital content in the urban fabric, recreation of architectural elements in digital form, visualisation of urban development projects in real time and much more. Despite the many possibilities, the main forms of integration that seem to take place vary according to the temporal direction. On the one hand, most projects that look at the past tend to focus on preserving architectural heritage by recreating it in digital form, and allowing visitors to access it in digital spaces often in Virtual Reality (VR)[20]. On the other hand, many projects that look towards the future of urban spaces make use of AR to help architects and communities to visualise future buildings or spaces in their contexts as overlays that are added to the current landscapes.

In this paper, instead, we wish to explore the connections between AR technologies and historical narratives and architectural spaces. In particular, we want to explore the possible use of Mobile AR (MAR) to act as a bridge between architectural spaces that hold connections and traces of historical events and the historiographical narration of the events themselves. In other words, we want to investigate how MAR can amplify such traces, visualise other historical elements, and guide users in experiencing and learning historical events. This exploratory research effort is connected with and influenced by the Anonymous project, which investigates the potential of XR in the creative industries by focusing on low-threshold technologies and strong connections between real and digital spaces.

To guide us in our exploration, rather than a specific research question, we have chosen to adopt a research through design approach by designing a MAR application dedicated to a specific historical event (the Battle of Tampere in the 1918 Finnish Civil War) and location (the Näsinlinna castle and the surrounding hill) , in close collaboration with the historians and curators of the Museum Center Vapriikki, which holds the historical artefacts and academic knowledge related to the event.

2. LITERATURE REVIEW

The role of XR and of both VR and AR specifically has been widely researched when it comes to architectural heritage. AR applications in cultural heritage touch various domains, including 3D reconstruction of artefacts, creation of virtual museums, gamification, education, and tourism [3]. Recent research highlights the potential of AR, especially in heritage preservation efforts, as well as to increase public understanding of historical sites [24]. In terms of preservation efforts, the ability to view 3-dimensional objects with realistic textures and materials in AR can be used to recreate heritage sites. While this is more common in digital spaces and VR [1], and is understood as a way to preserve architectural elements in a

virtual form, AR allows for the visualisation of the historical appearance of sites in their context, by superimposing digital reconstructions of lost or damaged architectural components onto current structures [12]. In terms of public understanding, existing research emphasises the informative benefits of enabling users to interact with historical contexts through AR and enhancing their engagement ([24], [10]). Users can comprehend the historical and contemporary value of heritage sites most sensibly by experiencing how architecture changes throughout time. Many studies that investigate the application of augmented reality (AR) for historical heritage focus on museum contexts or controlled indoor environments, such as reconstructions of artefacts, information layers, or manipulative elements like textures, details and materials to improve overall museum experiences and public engagement with historical content [14]. Outdoor spaces, however, while more challenging, host many historical architectural elements, and there is a strong potential for improvement in the use of AR in these environments [19]. Areas like AR for outdoor environment education have already started to break ground in this direction [11], but additional research is still needed when it comes to dynamic outdoor environments. Therefore, even though the literature on augmented reality is constantly expanding, there are many potential research directions that can be identified for the understanding of how AR can be applied in real-world architectural heritage settings, especially in outdoor spaces or natural contexts [3].

Augmented Reality can take many forms and, while there are currently different ways available to experience it, Mobile Augmented Reality (MAR) technology is emerging as a particularly useful tool for architectural heritage preservation. With MAR, users can engage and interact with heritage sites as active users since it allows anyone with a mobile phone to access the technology [28]. By using mobile AR applications, users can visualise and restore ruined structures, integrating layers of architectural information to showcase various conservation techniques and further data on real-world sites that traditional methods are struggling to exhibit [2]. M Thibault [25] highlights how AR enables digital overlays to superimpose on real-world environments, creating “media-generated alternative realities” (p.162). This technology enables heritage sites to be digitalised with historical narratives to provide users with an immersive experience. The presentation of digital reconstructions of historical events provides virtual access to sites or recreating historical events. These augmented reality applications are in place to facilitate the preservation and dissemination of architectural heritage and guarantee its ongoing significance in a modern context.

When considering mobile AR as the main technology, accessibility is a significant advantage of mobile AR in architectural heritage preservation. On the one hand, MAR does not require bulky or expensive headsets, but makes use of a device, the mobile phone, that many users already possess and habitually bring along. On the other hand, MAR allows broader, non-specialist audiences like students, tourists, and the general public to access the technology without prior knowledge, as it is based on a more familiar and intuitive interface [9]. However, there are still a few challenges that need to be addressed, like accurate localisation for overlaying the digital layer into real-world spaces. Many paths have been identified in previous studies to help us face these accurate localisation challenges. Previously, the Global Positioning System (GPS) was commonly used to create geo-location based AR experiences, but there are reliability issues with some use cases [23]. Another potential method is Visual Positioning Systems (VPS), which act as a location-based localisation technique much more accurate than GPS and uses computer vision algorithms to analyse visual data from cameras and compare it with known locations, enabling applications

in augmented reality, indoor navigation, location-based games and autonomous vehicles [16] Because of these findings mobile AR with VPS system showing promising potential technology for the development of this study.

If we look at existing literature and use cases, we can see that, while suggesting that MAR can indeed have potential when it comes to preserving historical architecture and enhancing public engagement with it, and MAR in particular can boost accessibility and interactivity, there are still several gaps to fill. First, many efforts to use AR for heritage preservation and engagement with historical artefacts focus on indoor and/or controlled environments. Developments in MAR and VPS technologies make it easier to deploy AR outdoors and therefore to focus on a wider range of architectural elements (e.g., facades) and spaces. Second, further research is required to explore how augmented reality might function not only as a tool focusing mainly on the visualisation of content, but also as a medium that allows some degree of interactive engagement with historical knowledge [29]. While this might be due to inheriting a "do not touch" mentality from traditional ways of engaging with heritage [26], it also hinders the use of the full potential of the technology. Third, despite the fact that several studies have emphasised the technology's potential to improve public education [15],[29], only a few of them have outlined how AR can be used to encourage active engagement in historical research.

With our study, we do not aim to fill all these gaps but to explore them and explore solutions that can address multiple challenges and opportunities at the same time. Hence, our research through design efforts will deal with the use of MAR and VPS technologies in an outdoor environment, the creation of content that allows some degree of interaction with historical artefacts, and engagement with architectural elements and dimensions that have rarely been approached before (currently building facades that will be "reskinned" to look at an older state).

Finally, This study aims to address these gaps by developing a mobile AR application that overlays historical artefacts and damaged architectural features onto the real-world environment of Näsilinna Castle while considering the practical challenges of outdoor implementation.

3. METHODOLOGY

Given the exploratory nature of this research, Research through Design (RtD) was chosen as the methodological approach. RtD emphasises the role of design practice as a means of generating new knowledge, making it particularly suitable for projects that involve emerging technologies and novel applications. This approach allows for iterative exploration and refinement, making it ideal for studies where research questions evolve alongside the design process [13]. Unlike other research methods and methodologies, which follow strict procedures to achieve specific results, often based on a hypothesis, RtD has an exploratory nature: it focuses on the design and creation of something new and, importantly, to learn something from the process. Gaver[13] argues that theory in design research should be seen as provisional and contingent rather than definitive and suggests that Research through Design should focus on producing substantial, conceptually grounded artefacts that reflect the insights developed through the design process.

This process emphasises the creative, reflective, and generative nature of research through design, where an iterative design activity plays a central role in knowledge generation.

The Research through Design (RtD) methodology follows an iterative testing and refinement cycle, incorporating designer insights and user feedback. This approach involves a continuous designing, prototyping, and evaluating process, where each iteration contributes to generating new knowledge and insights [13]. It advances through technical development and qualitative evaluation, recognising both as essential in producing meaningful findings within the design process.

Therefore, our study adheres to Gaver's [13] recommendation by adopting an RtD methodology and developing an AR application that progresses through iterative design cycles guided by user feedback and empirical testing.

More specifically, in coordination with our partners at the NEXR (Next Extended Reality) project, we have decided to design a MAR application dedicated to a specific historical location: the Näsinlinna castle and the surrounding hill. The castle was a key location in the Battle of Tampere, an important step of the 1918 Finnish Civil War, which marked the city and left behind several interesting historical objects conserved in the storage of the Museum Center Vapriikki. The castle itself has since been restored, and keeps no visible traces of the battle in its current form.

Based on Gaver's paper[13], we identified four main phases of the Research through Design process. The first phase, Exploring the context, involved close collaboration with experts from the Museum Centre Vapriikki to outline the historical and museological context in which our artefacts would be integrated. The second phase, Developing a design space, built on this context and the literature review to delineate the key features of the intended application and specify the software and hardware used in the process. The third phase, Refining and making, focused on designing the application by compiling existing materials, outlining a development workflow, conducting 3D modelling and content creation, and scripting interactivity. This work was iterative, with attention to user-centred refinement. The fourth phase, Assessment and learning, combined a small user study in which we collected qualitative feedback from expert users ($n = 11$) with self-reflection on the overall design process.

These four Research through Design (RtD) phases served as a foundation for broader reflections and recommendations that emerged through the iterative design process and were refined through continuous evaluation.

In terms of positionality, the authors of the present study include three men, and their ages range from the late twenties to the mid-forties. They are based in Finland, but their countries of origin are Sri Lanka, Italy, and Spain. They have backgrounds in architectural research and practice (1st and 2nd authors), human–computer interaction (1st and 3rd authors), and semiotics (3rd author). The authors hold a variety of views and experiences regarding XR technologies, ranging from curiosity about their potential to scepticism about current discourses surrounding them. We believe that these differences in perspectives and backgrounds, while still limited in range, strengthen the study by grounding it in a multidisciplinary perspective.

4. EXPLORING THE CONTEXT

This phase was dedicated to familiarising ourselves with events of the Finnish Civil War related to the Näsilinna area and with the traces they left or that have since disappeared in the architectural landscape of the city.

The Finnish Civil War was a divisive conflict that significantly shaped Finland's transition from a Grand Duchy under the Russian Tsar to an independent state. It took place from 27 January to 15 May 1918 [6] and, according to historical information provided by the Museum Centre Vapriikki, one of the most significant battles occurred in Tampere in the vicinity of Näsilinna hill. The battle caused heavy destruction to the built environment around Näsilinna and the surrounding area. Over the years, this area has undergone substantial renovations and restorations, and it now shows few visible traces of the conflict. Nevertheless, the war left lasting scars on the nation, shaping public memory and national heritage for decades [21]. For approximately a decade, the Museum Centre Vapriikki hosted an exhibition on these events titled Tampere 1918 [27]. Alongside historical context and maps, the exhibition presented artefacts collected from the battlefield immediately after hostilities ceased, including objects ranging from weapons to tools and even a doll. Although the exhibition was successful, it no longer exists, and the artefacts are now preserved at the

Museum Centre Vapriikki.

In recent years, the museum has initiated several projects to preserve the exhibition and its contents digitally. A digitised version of the exhibition is available via the Tampere 1918 website [27]. In addition, a digital experience of the battle has been created that uses a 3D recreation of the hills and their architecture (created by Zoan Oy). Users can choose one of the two sides in the battle and read a series of historical texts while viewing a short 3D animation that digitally reconstructs the events. Finally, Vapriikki and Zoan developed a VR experience, providing a digital replica of the physical exhibition (which also no longer exists). Users can visit this exhibition as a VR experience.

Our design was developed within the broader context of existing approaches that integrate digital and XR technologies into heritage preservation, with specific attention to this historical event. However, most existing projects primarily focus on virtual recreations of objects or spaces from the Battle of Tampere that are not location-dependent and can be accessed remotely via computers or smartphones. These approaches, while valuable, lack a direct connection to the physical spaces in which these events took place. In contrast, our research explores how AR can bridge historical narratives and architectural spaces, allowing users to engage with history in situ. By superimposing historical artefacts and architectural elements onto the original locations, our application offers a complementary perspective to existing museum initiatives and enhances spatial and contextual understanding of the past.

5. DEVELOPING THE DESIGN SPACE

This phase focuses on preliminary decision-making about project development, building on the context explored in phase one, our overall research objectives, and the gap identified through the literature review. Our exploration of the context led us to identify two opportunities for the use of MAR at Näsilinna. First, MAR

could be used to showcase the facade of the castle in its damaged state, revealing the physical and metaphorical wounds left behind by the civil war, even when the restoration has seemingly erased them. Second, MAR could be used to give users access to the artefacts collected after the battle, in their historical context, in a moment where there is no other way to access them. These opportunities are the areas on which we decided to focus our design efforts.

To guide the next steps of the process, we have set a series of key features for our final output. In particular, we want our AR application to:

- Enable users to explore the Näsilinna Hill area and interact with historical artefacts and architectural features through Mobile AR.
- Provide accurate overlays of 3D models of artefacts and the castle's historical façade on their real-world counterparts.
- Support educational engagement by offering contextual information about the historical artefacts and events.
- Ensure compatibility with commonly used mobile devices (iOS and Android), making it accessible to a wide audience.
- Offer way finding functionality to assist users in navigating the physical space and locating artefacts of interest.

These features outline an application that allows users to explore the physical space around the castle while interacting with a virtual recreation of historical artefacts and architectural elements superimposed on a real-world environment. By using mobile AR, we aimed to make the experience low-threshold, as it makes use of hardware (smartphones or tablets) that most users already own and are familiar with, without requiring additional devices, bulky headsets, or any advanced technical knowledge.

These features, then, guided us in the selection of appropriate technologies and design approaches in subsequent stages of development. In particular, we chose Unity as the primary development platform. In order to accurately localise AR content to the physical environment, we decided to use the Immersal Software Development Kit (SDK) because of its VPS functionality. In turn, the SDK is compatible with ARKit (for iOS) and ARCore (for Android) and ensures cross-platform functionality.

6. REFINING AND MAKING

The third phase focused on the development, testing, and bug fixing of the application. After having familiarised ourselves with the context and defined our design space, we had to make a series of concrete choices about what artefacts to show, what descriptions would accompany them, in which locations we would position them, and so on. In this phase, we worked in close contact with the personnel from the Museum Centre Vapriikki, which provided us with materials and expertise from its previous XR and digitalisation projects that were relevant to the Tampere 1918 exhibition.

Once we selected the artefacts and texts that we wanted to showcase, we created a technical Development Workflow for our AR application. The workflow involved several software tools and development frameworks. The primary tools used were Unity, Immersal SDK, Blender, ArchiCAD, and

Polycam. Each of these software played a role in creating 3D modeling, spatial mapping, and interaction systems that help create the experience.

This Figure 1 showcases the workflow used for the development process. These tools were used in developing the digital overlay interacting with the physical environment of Näsilinna Hill site, which allows users to explore both contemporary and historical environments.

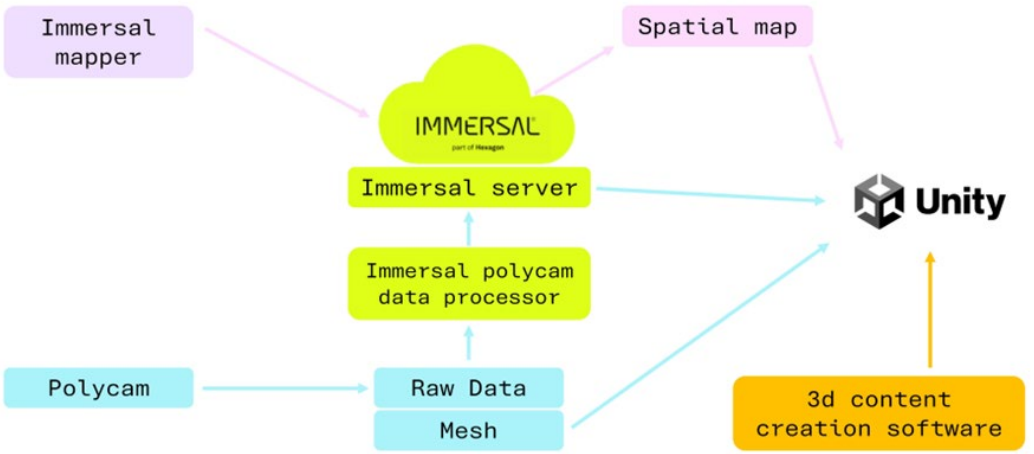

Fig. 1. Application Development Workflow.(created by the author).

6.1. SOFTWARE AND VISUAL POSITIONING SYSTEM (VPS)

Unity was selected as the primary development platform, providing flexibility in integrating various AR frameworks and facilitating the management of complex 3D environments. To ensure precise spatial alignment, the Immersal SDK, a Unity-based software development kit (SDK), was employed as the Visual Positioning System (VPS). This technology enabled the application to accurately overlay digital content onto the physical environment of Näsilinna Hill in real time, enhancing the authenticity and contextual accuracy of the augmented reality experience.

The development of the AR application began with the Immersal Mapper application, which helps generate spatial maps Figure 2 for localisation. The first step in the process was to map the study site by walking around the area and capturing a series of overlapping photographs in the app. The application then processed these images to generate a spatial map of the environment. Afterwards, the map produced by Immersal was imported into Unity for use in developing the AR application.

Apart from the Immersal mapper app, Polycam is another 3D mapping application used to generate a detailed 3D mesh Figure 3 of the ground planes and surfaces around Näsilinna Hill, which is also used for the Ground plane for AR navigation and content placement. Polycam also has the capability of capturing fine details of the physical environment, contributing to an accurate and stable AR experience while acting as a

second spatial map. Both of these map data ensured the precise alignment of AR components with the physical landscape and architectural structures.

The spatial data collected with Immersal and Polycam were imported to Unity to create a seamless representation of real world environment. These two data sets were combined to develop an initial robust localisation framework that provides the initial path to generate a successfully localised AR experience.

6.2. 3D MODELING AND CONTENT CREATION

Accurate 3D content was a crucial part of the development phase. It required a few specific 3D models to represent the historical artefacts from the Tampere 1918 period. Blender and ArchiCAD were widely used in the 3D modelling industry, especially in architecture, as a 3D modelling platform; they help create high-quality, realistic 3D models, which were used to create all the 3d models and damaged castle facades except historical artefacts. The references for the 3D models were technical drawings Figure 4, photographs, and documents provided by the Museum Centre Vapriikki to ensure the accuracy of historical details. Access to these materials and data from Vapriikki was governed by a contractual agreement ensuring ethical and authorised use for this study.

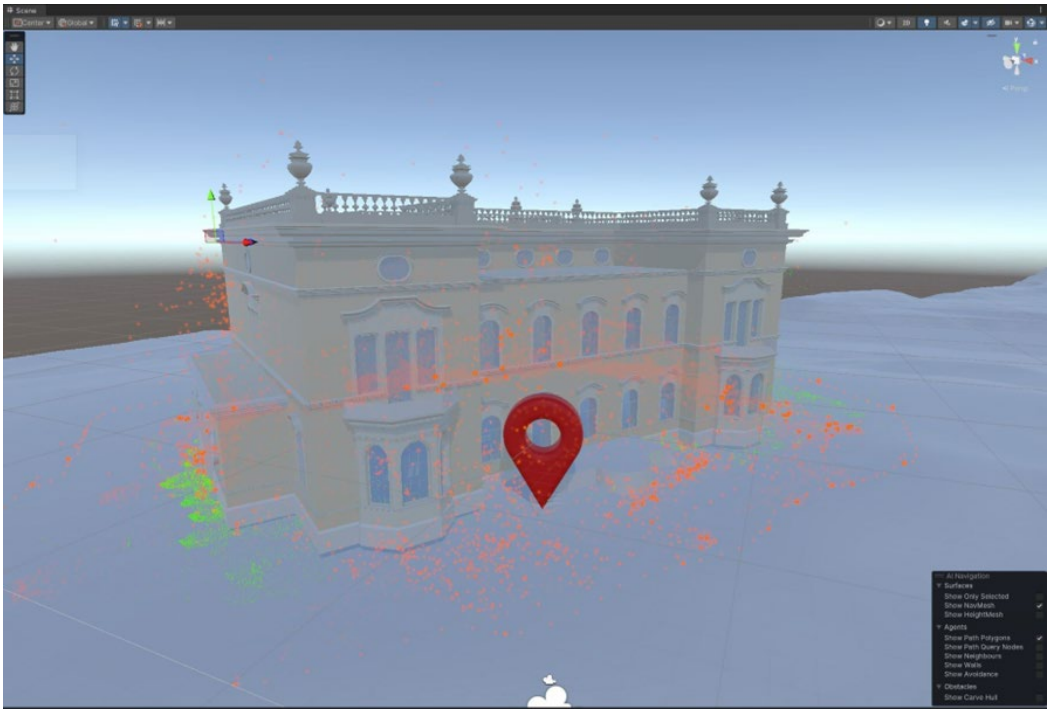

Fig. 2. Screenshot of Unity interface with the spatial map(green and orange dots) and 3d content. (created by the author).

The 3D models of the historical artefacts were provided by Museum Centre Vapriikki Figure 5. These 3D models are made by using 3D scanning technology to capture the textures and geometries that lead to a highly detailed replica.

Original artefacts of these models are currently preserved at the Vapriikki.

In addition to the artefacts, we created a 3D model of the destroyed castle façade Figure 6. The model was superimposed on the existing castle façade on site to show the way the castle façade looked during wartime, enabling users to interact with the 3D façade while moving around with their mobile devices, observing the wartime façade and the renovation of the present day façade.

As an additional content feature, audio and text transcripts were created to provide insights into the artefacts. A background audio introduction was incorporated, offering a brief historical overview and highlighting the architectural significance of the location and its connection to the historical event. Additionally, each artefact was accompanied by a text description Figure 7 available in both English and Finnish, ensuring accessibility for a wider audience and enhancing user engagement with the historical content.

Fig. 3. 3D mesh Generated by using Polycom application.(created by the author).

Using imported scanned maps of the site and other content, both Unity and Immersal SDK were utilised to develop the AR application. The Immersal SDK allowed for the integration of the spatial map into the Unity workspace, serving as the foundation for placing 3D content and enabling VPS (Visual Positioning System) localisation. The application was built using Unity's AR Foundation framework, which supports both ARKit for iOS and ARCore for Android, ensuring cross-platform compatibility and accessibility across multiple

mobile devices. Once the spatial map and 3D content were positioned in the designated locations, further refinements were made to ensure that 3D models of artefacts and architectural elements were accurately aligned with their real-world positions Figure 2. This precise placement was essential to achieving a seamless transition between the physical and digital environments, enhancing the authenticity and immersive quality of the AR experience.

6.3. SCRIPTING FOR INTERACTIVITY

An important aspect of the project is enabling user interaction with the AR artefacts and the environment. To achieve this, C# scripts were written within Unity to define how users would interact with AR elements; as a programming language, C# scripts enable users to visualise AR objects by pointing the mobile device's camera at them. As an example, when the user points the camera at an old wooden box (All the artefacts are placed inside wooden boxes that were scattered around the site), both a book with a description and an artefact will pop up on the mobile device screen. After that, users were able to tap on the screen to the specific 3D object to zoom in and rotate for the observations. In this process, as the user could explore the artefact in detail, it presents an educational and engaging value of the historical significance of each artefact.

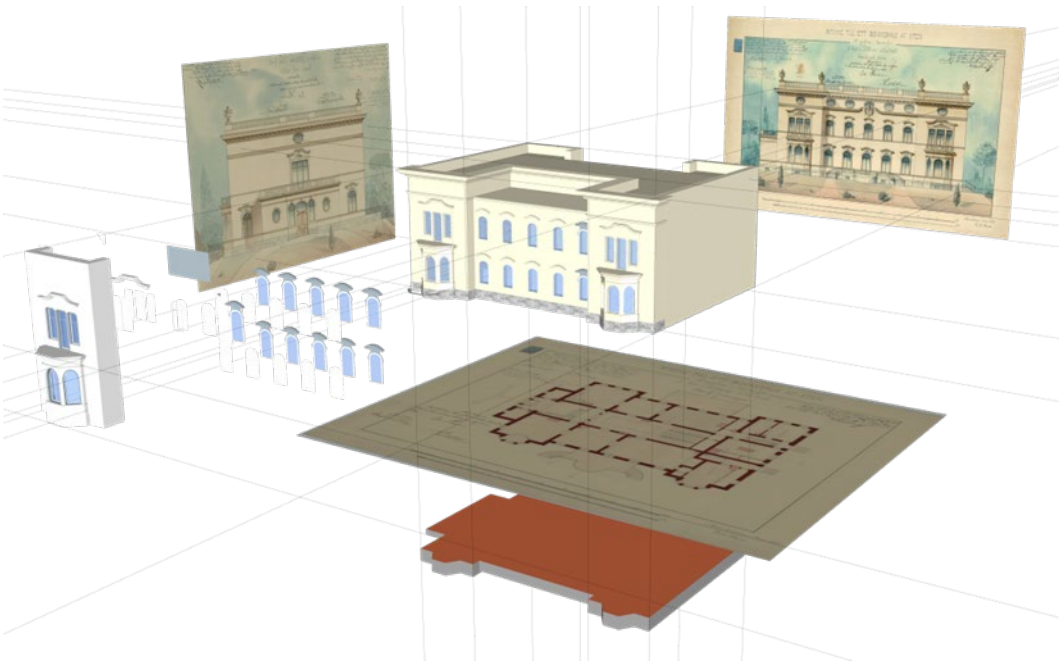

Fig. 4. Using historical architecture drawings and references to create an accurate model.(Created by the author).

Fig. 5. Some of the 3D scanned models were provided by Museum Centre Vapriikki.(created by Museum Centre Vapriikki).

The other interactive element is a 3D mesh of the castle's damaged vertical façade. Users could approach the façade with their mobile devices, and as they move closer, detailed layers of historical information will reveal themselves. For example, markers of battle damage or architectural details from 1918 would appear as overlays, guiding users to the historical context of the building's transformation over time.

Fig. 6. Finished model of the castle that represents the war situation. (Created by the author).

Fig. 7. From the Right: Text Description of the artefacts, How it is integrated into the AR layer as a 3D book. (Created by the author).

6.4. ITERATIVE DESIGN PROCESS AND USER-CENTERED REFINEMENT

Before the final development, early mockups of the AR application were created to demonstrate the core interaction mechanics and visual style of the AR experience and used to develop the application further. Coherent with Research through Design processes, we deployed an iterative process to test, refine, and evaluate the app, allowing the application to engage with real-world user interactions. The mock-ups served as a proof of concept, enabling us to test basic functionality and gather preliminary feedback through short interviews with a few users (n=4) with backgrounds in architecture, recruited from our research environment. The simple mockup scenario consisted of a virtual AR object representing an old wooden box placed on the ground near the Näsilinna castle. When users pointed their mobile or tablet camera at the box, the 3D scanned recreation of a historical artefact would emerge from the box, accompanied by a description of the object and its historical relevance, visualised on a digital parchment. The mockup also included the possibility to visualise an incomplete version of the damaged façade layer of the castle overlayed on the castle itself.

Participants provided feedback on different aspects of the application in short interviews, offering suggestions on how to improve both technical and educational values of the artifact. As an example, one participant suggested that providing extra contextual information about the artefacts, such as their use in the Tampere 1918 events, would significantly improve the educational impact of the experience.

Additional refinements were made to improve the User Interface (UI), making it simpler and easier to navigate. Following the feedback collected, the artefact-selecting drop-down menu was simplified to reduce confusion, and an audio description was added to guide users through the exploration process. These changes were made with the goal of making the application as user-friendly as possible while maintaining its educational focus.

Testing was the most crucial step for this kind of development to achieve the desired results because it enables the identification and resolution of any technical issues that occur in the development phase. Once the application's core functionality had been developed, continuous testing was conducted on-site at Näsilinna Hill to ensure that the application performed well under real-world conditions. Also, on-site testing was important for evaluating the performance of the VPS localisation system and the accuracy of overlays on the physical site. This testing phases faced several challenges, including localisation failures under poor lighting and in shaded areas, failures under rapidly changing weather conditions, or seasonal environmental changes. These issues were particularly prevalent during the autumn months in Finland, when the weather conditions can change drastically over a short period of time.

To address these challenges, we created multiple spatial maps that could be switched depending on the environmental conditions. This ensured that the AR content of the application localised accurately even when lighting or weather conditions fluctuated.

In addition to localisation issues, several minor bugs were identified during the testing phase. Including delayed responding time when the user interacted with the object and occasional glitches in the wayfinding system. These issues were addressed by optimising the C# scripts used for object positioning and improving the back-end processes that operate the wayfinding functionality. This phase marked the final round of testing, where the focus was on ensuring that the application ran smoothly on both iOS and Android devices.

6.5. FINALISATION AND DEPLOYMENT

The application was optimised to ensure mobile performance, smooth interaction, and responsive AR elements, even on mid-range devices. The 3D models were optimised by reducing polygon counts and compressing textures without compromising visual quality. This optimisation process ensured a continuous, high-quality experience for users regardless of their device.

Gradually the development of final project, the application was deployed for user testing at Näsilinna Hill Figure 8. This made the beginning of formal user experience evaluation phase, where qualitative data were collected on user engagement, satisfaction and educational and experiential outcomes.

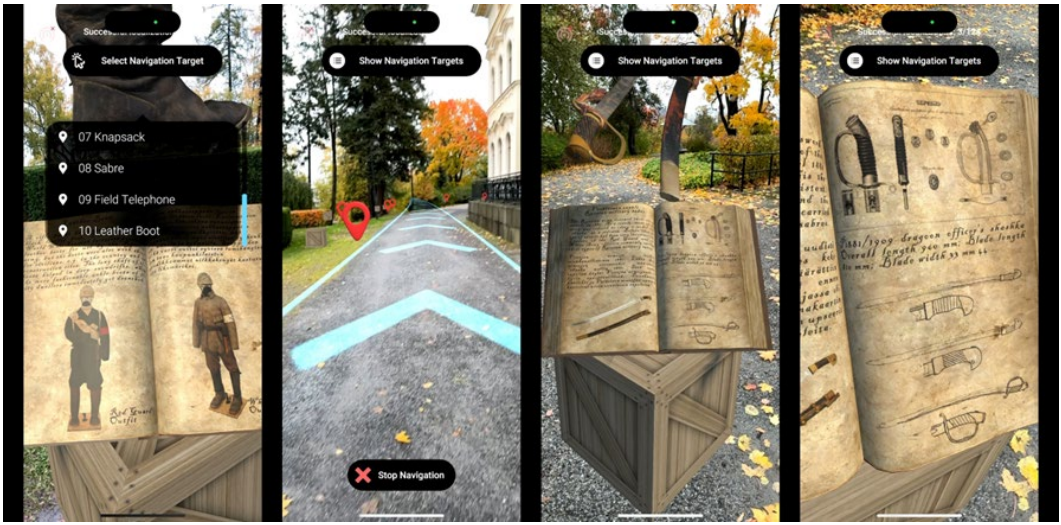

Fig. 8. Screenshots of the application during onsite testing. From the Right: Navigation menu, Navigation pathway, Artefact, and the description, Detailed descriptions. (created by the author).

7. ASSESSMENT AND LEARNING

The fourth phase, focuses on what can be learned from the design process, but by engaging with the users and though our own self reflection.

7.1. USER FEEDBACK

After the finalisation of the application, we started a phase of user testing involving users from different professional backgrounds to collect qualitative data through a short survey with open ended questions. Before their involvement, all participants were informed of the study's purpose, their right to withdraw at any time, and the intended use of their anonymised data for research analysis and publication. Written/verbal informed consent was obtained, and no personally identifiable information was collected to ensure confidentiality. Data was aggregated and analysed to derive insights while safeguarding participant privacy.

The participants (n=11) were recruited through the Anonymous Project networks, and had backgrounds in architecture

(n=4), history and heritage (n=2), design (n=2), and other fields of academic research (n=3). According to self reported data collected as part of the survey, eight participants had no prior experience with augmented reality, and two had two years of experience in AR technologies. Simultaneously, respondents experience in architectural heritage or historical preservation ranged from none to more than

ten years for one participant. This diversity provided a comprehensive set of perspectives on the usability, feasibility and educational potential of the AR application.

Participants were asked to fill an online questionnaire immediately after testing the app. The questionnaire consisted on six open ended question focusing on: the application effectiveness, ability to integrate virtual artefacts with the real-world environment, ability to help the acquisition off historical knowledge, accessibility, potential in heritage preservation, and on possible improvements. Due to the small number of participants and the exploratory nature of the study we decided to focus exclusively on qualitative data collection, which is particularly indicated to understand the user experience of the design and the design process, and especially suitable for projects like architectural design [8]

[18].

We analysed the data collected from this survey, as well as the observations emerged from the short interviews after the mockup, making use of content analysis, which is a simple and useful way to helps analyse qualitative data in explorative research through design studies [7],[4]. Our content analysis, was articulated around three key sections, common to other application of the method ([7], [4]), namely: user engagement, user observations, and recommendations for future developments.

7.2. USER ENGAGEMENT WITH AR IN HERITAGE PRESERVATION

The first impression of the application experience was generally positive, as identified by the discussion with the users onsite. Several participants mentioned that it offered an engaging and immersive experience of interacting with historical artefacts and architectural elements of Näsilinna castle. Participants consistently mentioned the importance of engaging with 3D models, moving around the site, and interacting in a physical and digital world. For example, the "participant 7" with 1-5 years of experience in architectural historical preservation mentioned,

"It was impressive to study the objects at the site like as it is where those were decades ago. And the explanations were informative."

However, while many participants mentioned digital and physical interaction as a key strength, some of the participants mentioned the challenges with the user interface and navigation of the tools. The first participant with a

User Experience and Accessibility background mentioned,

"The UI is a bit confusing at the beginning. A clearer intro or guidance would help."

Another user which is Participant 5 suggested that defined paths and a clearer interaction solution would improve the smoothness of experience.

The general technical performance of the AR app was met with mixed reviews. Many of the respondents mentioned the app functioned well, especially with the 3D rendering of the models and localisation of the app at the Näsilinna Hill site. At the same time there were few issues mentioned about the localisation speed and the accuracy. An Architect and Professor, The fifth participant, mentioned that,

"It was rather effective, although with some technical problems yet, mainly related to the connection speed and localisation."

A recurring technical issue was the misplacement of AR objects, particularly in poor lighting or in different weather conditions. Respondents found a challenge in the Visual Positioning System (VPS), which sometimes struggled to accurately place artefacts, placing the objects sometimes a few meters above or into the bushes. This challenge has been repeatedly reported since the testing time was not taken under the same conditions, and there are rapidly changing autumn weather conditions. Addressing the localisation issue will be a critical aspect in the future development of AR applications, as users should receive a smooth and reliable experience in observing historical artefacts.

7.3. USER OBSERVATIONS ABOUT AR IN HERITAGE PRESERVATION

One of the key outcome from the AR application is its ability to blend in with contemporary architectural space at

Näsilinna castle. Users found the overlaying of wartime castle façade onto present façade engaging and informative. A Participant 9 mentioned that,

The app "The damaged walls of the castle were very detailed, and it's a really good way to look into the past that has already disappeared from the physical world."

Participants were able to navigate around the site using the app's way-finding system, which guided them to their desired places. As noted in the survey, participants found this feature interesting. One user compared the experience to geocaching,

"the navigation was clear, but I would have preferred more of a challenge, like solving puzzles to find the next object."

7.4. EDUCATIONAL OBSERVATIONS OF THE AR IN HERITAGE PRESERVATION

A key objective of the project was to enhance user understanding of the historical events of the Finnish Civil war that happened in Tampere 1918 and the historical architectural value of Näsilinna castle. Several users, including the users who had no experience in architectural heritage, mentioned that they learned new things about history through AR experience. One user commented,

"The voice and 3D images helps. I knew nothing before. I feel like I know something now about history."

This indicates that using AR has potential for delivering information and interacting with users. Participants appreciated the presentations of information through audio, text and 3D models. s the user feedback was considered improvements, some users suggested that the historical artefacts could be connected to some sort of a related specific place on the site. A user (Participant 7) with an architectural conservation background mentioned,

"It was impressive to study the objects at the site like as it is where those were decades ago. And the explanations were informative."

Participants found the AR application adds value to the experiential learning of architectural heritage. A participant

(Participant 5) who is an architect and a professor, found that, the app "This is a totally new and interesting material to study comparing the methods I have used to study architectural heritage so far. I think students will be eager to interact with this technology to do their studies. For me it's easy to understand and more likely to keep in memory."

This experiential learning use of the app identified by the participants with a teaching background suggests how the app could be used to deliver information in a significantly interactive way, which indicates future possibilities and potential future studies. This interactive nature of the AR application was identified as a special learning object over traditional methods. A response showed that (Participant 8),

"It's not like reading books and observing historical pictures. It was learning while being on site."

This involves the approach combined with spatial interaction, enabling the users to understand both the historical artefacts and the architectural transformation of Näsilinna castle through time. The participants were identified with AR applications in architectural education, especially engaging students with experiential education. Several participants based on architectural education background identified the ability to study detailed 3D replicas and architectural renovations in real-world contexts as offering a significant advantage over traditional learning methods. The sixth Participant with an architecture background suggested,

"This is a totally new and interesting material to study compared to the methods I have used before. I think students will be eager to interact with this technology."

Additionally, the hands-on nature of the application, combined with tactical digital elements, engages in a practical way with the young audience who may not be interested in traditional historical education.

7.5. RECOMMENDATIONS FOR CONTINUED DEVELOPMENT

A primary development opportunity that emerged from the survey was improving the application's storytelling and gamification aspects. Simply, gamification means adding mechanics that are used in games to non-game situations. Several users suggested incorporating puzzles and wayfinding clues to make the AR experience more engaging. These features would allow users to feel strongly engaged in the historical exploration and fill them with a sense of accomplishment. One participant with a background in architectural conservation suggested,

"The content needs to be gamified in the sense that finding the objects involves some kind of puzzles and clues, giving the user satisfaction and the story a pull."

This approach will align with research through design methodology by providing opportunities for iterative developments.

Improving the application's user interface (UI) is a huge improvement opportunity. Another participant's suggestion was to make the AR object zooming and rotating controls more intuitive. The fourth participant, who is a historian, mentioned,

"Using two fingers to rotate the model was unfamiliar to me. I expected to be able to swipe with one finger, which would have been more intuitive."

This option is impliment in the application in the testing processes and used for the test in the later participants.

A few participants also questioned expanding the application's multilingual options. Currently, the application has introduction audio in English and artefact text descriptions in both English and Finnish without audio descriptions. Nineth participants (from the Field of Architectural Heritage Conservation) noted adding another language to the audio description, like the Finnish language.

"I wish there were more audio descriptions for each artefact in different languages, at least in the Finnish language."

8. DESIGN CONSIDERATIONS

The development and iterative refinement of the AR application for Näsilinna Castle, as well as the survey and interviews, have provided meaningful insights into the opportunities and challenges of integrating AR with heritage sites, which led to several design considerations.

These considerations can be the base for future projects involving the use of XR, and in particular MAR, in connection with heritage sites. Due to the exploratory nature of this study, the following considerations are preliminary steps, illustrating possible resources for future designs and refinement.

- Outdoor MAR can be a tool to engage with large heritage sites. Despite some technical difficulties, the technology seems to be mature enough to allow an easy use of MAR in outdoor spaces and with changing weather conditions. This can support educational and conversational projects to engage with large heritage sites, architectural complexes and potentially urban areas as well. Researchers, conservationists, and developers interested in exploring different ways of engaging with large heritage sites, then, can easily introduce low-threshold MAR applications as part of their resources.
- AR can bridge between museums and heritage sites. Museums offer secure and controlled environments for the conservation of historical objects, while heritage sites embody continuity with the locations of historical events. AR can offer a bridge between the two by using 3D scans of artefacts that are conserved in museums, and allowing the general public to visualise them in the original environment. While many collections are undergoing digitisation efforts for preservation, it is likely that in the future most historical artefacts might posses some 3D digital counterpart. This will offer a wealth of 3D objects, whose counterparts might often not be visible for the public, to be showcased safely as part of outreach and educational efforts, as well as touristic and cultural applications.
- "Reskinning" can be a new strategy for engaging heritage through XR. While AR has often been used to showcase what is no longer there, in Battle of Tampere AR we have explored the possibility to show instead earlier stages of existing buildings. We believe that this can be support more multi-faced and deeper engagements with history and heritage. Rather then present historical sites as something that existed and has been lost, "reskinning" showcases change and mutation (rather than destruction) and can bring to the surface scars that have been hidden beneath fresh coats of paint in restoration efforts. Traces of conflicts, of negotiations, of iconoclastic periods, of changes in fashion and taste that are often hidden under the last layer - or efforts to restore heritage to their original form - can then be made visible and hence problematise narratives and offer more nuanced historical depth.

- AR can improve the engagement with history in heritage sites by providing active interaction. By allowing users to manipulate AR elements, compare past and present architectural states, and engage in explorationbased experiences, AR can serve as an immersive educational tool, fostering active learning and engagement with cultural heritage. In our application, having on site experience, immersive visual and audio, real-time manipulation of the real structures in the digital layer, and the ability to compare both current and past situations at the same time, including exploration games-like experience, seemed to enhance user engagement with the location and application and support their learning experience. Similarly, a curated use of AR, and especially of the possibilities of its affordances, can be used to promote a nuanced and multi-faced relation between users, historical artefacts, and heritage sites.

In conclusion, our exploratory study was able to inspire several design considerations that can help guide the development and use of AR in heritage. At the core of this study, we have witnessed how AR can revive lost architectural elements and bring history to life in a way that conventional preservation methods cannot. This realisation underscores the importance of leveraging emerging technologies responsibly, ensuring that they complement, rather than replace, traditional approaches to heritage education.

8.1. LIMITATIONS

Our research effort was explorative, and therefore features several limitations. First, scalability is major challenge for our study. Architectural heritage varies by location, culture, and environment, hence it is impossible to find one-size-fits-all design solutions on how better use AR in heritage. Further research and experimentation is needed to identify common patterns and develop adaptable guidelines, ensuring future studies can be more scalable and applicable across diverse geographical and environmental conditions.

Second, the number of interviewees and respondents to our survey was limited, and all the participants where in some way familiar with the project and/or the researchers. Importantly, the participants were representative only of some of the possible target groups of our application. While their involvement in our design process was mainly oriented towards gathering expert feedback on the different areas of interest of the application (architecture, heritage, XR) to support our research efforts, we stress that actual development projects of similar applications should be human-centred and involved diverse possible users in all stages of the design.

Third, there is a significant difference in user feedback between those with prior experience in AR and those without. This suggests that the novelty effect might have influenced the evaluation and feedback we collected. A broader study would provide deeper insights into how the general public engages with a project of this nature, leading to a more comprehensive understanding of its impact.

Finally, there is still a lot of potential to further develop the app. Based on the suggestions of our participants alone, there is space for developing gamification elements (for example by introducing puzzles, quests, and discovery-based tasks) that can make AR applications more engaging, encourage users to explore, and increase the quality of engagement time. Also, addressing missing accessibility features like text-to-speech, multilingual options, and age-based transcripts by using Gen AI can increase this user engagement and accessibility for diverse audiences, such as people of different ages or with accessibility needs.

9. CONCLUSION

In this study we have developed Battle of Tampere AR, a mobile application dedicated to the Näsilinna castle heritage site that made use of MAR to allow users to visualise and interact with historical artefacts preserved in the Museum Centre Vapriikki as well as an overlay to the castle's façade showing the marks of the battle. This design was part of a research through design effort that aimed at exploring the potential of AR technologies for cultural heritage and, in particular, in regard to outdoor spaces and architecture. Our research led us to formulate four design considerations, namely: Outdoor MAR can be a tool to engage with large heritage sites; AR can bridge between museums and heritage sites;

"Reskinning" can be a new strategy for engaging heritage through XR; AR Interactivity to Enhance Engagement and Learning in Heritage Sites. All in all, despite its small scale, our exploratory study suggests that AR reconstructions can be used to promote a deeper understanding of historical events and architectural changes and can offer new interesting strategies for architectural heritage preservation and historical education.

As heritage is a nuanced concept, and heritage sites can greatly differ, our considerations are not to be generalised, but rather they aim to be the basis for further research and exploration. Future research could investigate, for example, how AR applications could be expanded to other cultural heritage sites and how they could be combined with, for example, gamification and other engaging technologies.

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