

Large Room Scale Augmented Reality in an Unaltered World Heritage Site

M. Olbrich¹ , A. Zapf¹ , C. Stiegemann², A. Pröbe³

¹Fraunhofer IGD, Germany

²Kirchengemeinde St. Stephanus und Vitus Corvey, Germany

³Erzbistum Paderborn, Germany

Abstract

Augmented Reality (AR) has found use in cultural heritage exhibitions in many forms during the last decade [BBG 22], but usually by preparing the environment with markers or focusing on smaller exhibits like single statues [KKK* 14]. In this paper we present our approach to apply the technology to a larger unaltered environment. We show how we use Augmented Reality in this cultural heritage site to superimpose what was lost in time over what is preserved today, and virtually illustrate different aspects of the creation or reconstruction. Furthermore, we explain how the application, which is purely an extension of guided tours, is set up so that the guide can control the visitor's experience and steer them to the current point of interest. In this way, the visitor moving through the room is virtually shown the originally existing rich design of the cultural heritage site and is able to access it.*

CCS Concepts

• **Computing methodologies** → **Tracking; Mixed / augmented reality;** • **Human-centered computing** → **Graphical user interfaces;**

1. Introduction

Approached with the task to create an AR guided tour companion application on behalf of the Catholic parish of St. Stephanus and Vitus Corvey in 2017, we were faced with a World Heritage Site with difficult lighting conditions and few possibilities to change the environment due to the highly sensitive findings in terms of conservation. Since 21 June 2014, the Carolingian westwork of the former monastery church of Corvey has been recognized by UNESCO as a World Heritage Site. The environment in question, the St. John's choir – so-called „Johanneschor“ – on the upper floor of the westwork, a large square hall surrounded on three sides by galleries, contains little descriptive information about its historical significance apart from a few strange openings in the plaster above the arcade pillars and a few places where faded fragments of the original mural paintings are visible. As the liturgical center of the Carolingian westwork, the St. John's choir was originally the richest in architecture and painting. However, the finds can only be guessed at in large parts, as many areas are irrecoverable and only rudimentarily preserved. A closer look at the exposed walls reveals sinopias – preliminary drawings for life-size stucco figures – whose only sculptural remains were once found in the floor among rubble and are now kept in an archaeological depot. The faded fragments of painting on some of the arcade pillars, walls and arches can only hint on how richly and colourfully decorated with vegetal motifs these walls once had been before they were turned into uni-

form white, centuries ago. Especially on the western side gallery, not only decorative ornaments are visible, but mural paintings with scenes from ancient mythology, which can be traced here for the first time north of the Alps, that seem misplaced on first sight. On the opposite side of the hall, a strange coffered wooden construction with small doors also turns out to be a later addition. It is the rear side of the Spring-Chest organ, installed 1681, which separates St. John's choir from the nave. The originally rich sculptural and painterly decoration of the hall is in no way conveyed to the visitor today. The findings are only accessible to the trained eye and it is difficult to convey with words and a few pictures what the St. John's choir looked like at the time it was built.

2. Related work

In the past, we had the chance to get a lot of experience with augmented and virtual reality in the context of cultural heritage and related fields. Projects like Chess [KKK* 14] allowed us to gain expertise in superimposing cultural heritage objects with additional information in text, pictures and even in 3d. With Schloss Burg, we extended our experience in working with larger environments, and in projects like our VR exhibit as part of Expedition Grimm, we acquired knowledge in virtually resurrecting lost environments. In [KSE* 18] we summarized some of the patterns we used to convey information in augmented reality. More recent projects like

Mixed Reality for Cultural Heritage [PWK19] show and compare different XR technologies and their use in cultural heritage, but even beyond of traditional AR and VR hardware, projects like The Revealing Flashlight [RRL*14] show how interactive projection based approaches can be used to augment an artifact.

2.1. Motivation and vision

The World Heritage title obliges the owner to make the Carolingian heritage accessible to all visitors, but at the same time, the aura of this outstanding place of remembrance of monastic life should be preserved. While the structure on site may not be changed to show what this hall once looked like, a virtual representation can provide a lens for visitors to look back in time and explore the environment as it once was. The AR application entitled "Guarded by Angels - In the Celestial City" gives visitors a vivid idea of the original richness of the decorations, their meaning and significance. Thanks to intensive scientific research, it is possible to reconstruct the structure and colouring of the original mural painting of the hall in large parts [CS07]. Comparative examples from manuscripts and mural paintings from the period of origin in the 2nd half of the 9th century help in reconstruction of decorations and motifs. In addition, this is also to be a tool to explain how all this information was uncovered and reconstructed. To meet this objective, we focused on a few selected scenarios we wanted to present:

- Uncovering of sinopia and reconstruction of former stucco figures
- Allow a detailed look at the old stone slab, whose lettering with its now long-lost golden letters adorned the entrance to the church for centuries
- Reconstructing the view into the first Carolingian basilica
- Recreation of colourful ornaments and painted friezes that once decorated every arch and edges
- Make faded wall drawings visible to visitors and explain their significance

All this needed to be targeted at a wide range of visitors, from digital natives to cautious digital novices.

3. Strategy and concept for the application

3.1. Asset Generation

The building, and the targeted sanctuary in special, has received a lot of attention from historians and art historians over the years, but all results were in text and drawing [CS07], apart from a coarse scale model. The findings allow detailed insights into the artistic work process, whereby the digital application is able to open up the genesis of the painting and the design of the stucco figures in a completely new way. The starting point is the question of the technique and execution of Carolingian mural painting and architecture. This leads to the task of conveying the artisanal techniques of the time. Short film sequences illustrate individual work processes such as the design of the stucco figures. Modelling the stucco figures was a particular challenge. Information that has been lost through the destruction of the figures can only be recovered through hypothetical visualization procedures. Considering the preserved finds, the life-size figures have to be modelled and painted in colour. With

the help of mobile devices, visitors can experience the colourful Carolingian decoration of the westwork and obtain a new thorough understanding of how these works of art once looked like and how they were created [BRBBG*20]. To overlay information on the real environment, we needed a 3D representation of the room's interior. To convey the massive changes to the building over the years, complete outer skin models from different eras were required. Based on existing architectural surveys and reconstructed historic data, 3D models representing these epochs were build. The interior models were later texturized based on historic information. Smaller objects needed for the application could be directly scanned in 3D with CultLab3D's process [SRT*14]. This included artifacts like the found statue fragments, which were transported to CultLabs3D's lab location and scanned with an automated process.



Figure 1: Virtual representation of the stone slab (3D scanned).

Other objects to be scanned were immobile, which were created with a photogrammetric approach. This included the huge stone slab (see Figure 1), as well as the opened-up mural surfaces that contains the sinopia. While not much of the statues could be preserved, we needed some models to explain the creation process, starting with the sinopia and finishing with the coloured statue. This was solved by recreating the statues in 3D, taking the sinopia as well as reconstruction drawings of the three-dimensional figure as a starting point and the left-over fragments as an information source about colour and surface structure. Statues from the same period served as a reference. The resulting models were later iteratively refined with an art historian.

3.2. Environment Tracking

Due to the curator's decision to only allow the application on in-house devices, we were able to simplify development since we were able to focus on a single platform, without taking different performance devices into consideration. Since no additional markers could be placed in the environment, and a lot of the features in the room are self-similar, marker and model-based tracking approaches had to be dismissed. [BPCRLV19] experienced similar problems on natural stone walls. Our solution was to make use of image tracking to recognize the positions of the differently shaped openings in the plaster where the rubble stones are visible. With at least two locations recognized, a umeyama based approach (with some additional constrains) was used to align the 3D model to the real environment. Two recognized locations are sufficient here, because we reduced the DOF to 4 (up stays always up). While we welcome the simplicity brought by a single platform, the chosen approach could simply be translated to Google's ARCore, which itself has already a widespread usage in the development of augmented reality applications for cultural heritage sites [VGPM19].

3.3. Interaction and Visualization

As for visualization, we needed to consider that the app is primarily targeted at visitors that have booked a guided tour and will stay for roughly 10 - 30 minutes on site. Every visitor receives a tablet, regardless of their experience with such a device in general or with the app in particular. The main goal for the user interface (UI) – besides a pleasing visual appearance – was to provide a user-friendly interface, that is not overwhelming on the first impression and should also be self-explanatory where needed with a very low learning curve for interaction. We also ensured that visitors cannot break the UI or get stuck in the interface since the available interactions are broken down to simple actions without dead ends.

TRACKING INITIALIZATION. To make sure that the user is initializing the tracking correctly, we show a noticeable box on startup that explains the task for initialization in one short sentence to quickly capture the request. Additionally, an image represents the visual impression of the important tracking targets that are mentioned, so that the user can find them instantly (see Figure 2).



Figure 2: An info box being displayed in the UI for tracking initialization with the prompt: “Pan around the room with the tablet and aim at some of the wall patterns”.

“TABLET DOWN” GESTURE. When dealing with large scale models or room sizes as we did in this project, there will most certainly occur situations where the user needs to hold the device overhead or in a similar uncomfortable position to view specific regions. Some visitors might not be able to perform those poses or cannot hold the position for a certain amount of time. Therefore, we implemented a “tablet down” gesture, which gets activated when the user is lowering the device down to a defined angle. When our app is recognizing this state, we are switching from AR camera to a VR view, showing the perspective of interest without the need to align the device. It is important that the VR perspective is well chosen in a way that the UI is still rendered without overlapping regions of interest since this view is fixed and cannot be moved by the user. Another feature of the “tablet down” gesture is that especially for unexperienced users the fear of failing with new technology can be reduced, since with this option the user will still be able to follow along the tour in VR.

AR-OVERLAY. We use a room-scaled main model that is neutrally textured by default, just like the present state of the space in the real world. The room model is always displayed and overlaying the camera view fully. Despite rendering the whole room model on top, we realized the impression for the user as being very realistic. This approach supports us covering the large area of approx. 14.5 x 9.5 meter and ensures that there is no offset between real world and overlaid geometries over time even if the tracked model’s offset might not be totally accurate, which would normally

lead to a poor user experience. Nevertheless, we make use of additional meshes with textures to individually overlay the room model with vanished wall paintings or reconstructed ornaments (as seen in Figure 3) without altering the materials of this model on a large scale.



Figure 3: Screenshot with the texturized model showing vivid colours and reconstructed ornaments.

WORKING PROCESS FOR STUCCO STATUES. With the AR app we make visual enrichment available that could not be illustrated in this way before. The working progress for stucco statues, for example, shows how these statues once were created and attached to the walls. Animations like this can be triggered individually and support the guide in addition to the spoken explanation. The visitors can experience the presentation at the exact spot on the wall (the former location of the stucco statue, see Figure 4) by panning the tablet to this point of interest. As mentioned above, it is also possible to view this in VR by performing the “tablet down” gesture. The elements used by the animation are 3D scanned models from original objects found during research years ago.



Figure 4: Screenshot from the animation of the working process for stucco statues.

3D SCANS. To further present original scanned objects in 3D and explain specific features (e.g. colour remains on stucco fragments) to visitors, we implemented an object viewer that can be triggered by the guide. When displayed, the viewer shows a 3D-scanned object that can be manipulated through the visitor’s tablet. The user can rotate the virtual object and move it to predefined perspectives by tapping on available buttons. This enables the visitors to explore the objects themselves as the guide is outlining details about it.

3.4. Following the Guide

While visitors can move around and explore the environment, the guide controls the visibility of additional information that appear on all devices. To enable this control, the devices of a tour group need to be linked together. Since all devices share a common WIFI

network, we set up a communication server that can also be used to show information about all the connected devices to simplify maintenance. This information includes data like battery charge, device state (ready, in a session, offline) as well as the current software version. The guide is able to list all currently ready devices and add them to his session.

GUIDE/VISITOR INTERACTION. As described above, each visitor receives a tablet for this part of the tour. The guide can also just use any tablet available and access the special guide UI via a login with passcode. While the group gathers in the center of the room, the visitors' tablets show a starting screen with a notice to wait for the tour to begin. The guide can now select the devices on his screen that are ready to take part in this session. As soon as the session starts, the AR view gets active simultaneously on all visitor tablets that are taking part in this session. The users are prompted with the notification popup for tracking initialization (as shown above) and will begin panning the device around to initialize the tracking. Within the guide UI there are different topics to choose from, so the guides can individually compose their content spontaneously for each session dependent on the groups' interest. Each topic comes with prepared notes subdivided by sections and a set of trigger buttons which allows the guide to trigger content of interest to display on visitors' tablets (see Figure 5). This content ranges from 3D models placed in AR, 3D scanned objects in VR that can be manipulated by the user (in the object viewer), animation sequences in AR/VR as well as videos or images to further illustrate specific topics.



Figure 5: (a) Guide UI with trigger buttons at the bottom. (b) Stone slab placed in AR. (c) Object viewer for visitors.

4. Discussion / Conclusions and Outlook

Some of the guides were sceptical about using the technology for their tours, but the biggest concern was the handling of the system. The content of the application was perceived positively across the board by both the guests and the tour guides. During a big celebration on the occasion of the 1200th anniversary of the heritage site, a preview of the application was given to guests and the press, which received very positive feedback. With the public introduction earlier this year, some problems arose that had to be solved, and the application can now be used for public tours.

We are planning run an user evaluation as soon as all guides are used to the system, so we can get some reliable feedback from guides and guests. With these results we are planning on a more extensive publication, which will also allow us to talk more about the technical details which would have exceeded the focus of this work.

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