Spatializing experience: a framework for the geolocalization, visualization and exploration of historical data using VR/AR technologies

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ABSTRACT
In this study we present a novel ICT framework for the exploration and visualization of historical information using Augmented Reality (AR) and geolocalization. The framework facilitates the geolocalization of multimedia files, as well as their later retrieval and visualization through an AR paradigm in which a virtual reconstruction is matched to user's positions and viewing angle. The main objective of the architecture is to enhance human-data interaction with cultural heritage content in outdoor settings and generate more engaging and profound learning experiences by exploiting information spatialization and sequencing strategies.

Categories and Subject Descriptors
H.5.1 [**Multimedia Information Systems**]: artificial, augmented, and virtual realities, evaluation/methodology.; H.5.1 [**Information interfaces and presentation**]: User Interfaces – graphical user interfaces (GUI), User-centered design.

General Terms
Design, Documentation.

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Keywords
Augmented Reality, Historical 3D Reconstruction, Spatial Narratives, Cultural Heritage.

1. INTRODUCTION
One of the key challenges in the field of Human Computer Interaction is to develop information systems that can help us to make sense of big amounts of data produced nowadays by several scientific fields [3, 7, 12]. Particularly with the increase of public access to cultural heritage databases, the field of historical research and education also cope with this challenge, generating a need to update guidance and interpretation systems. Developments focus on the improvement of large-scale content access [5] as well as the conversion of information into digital forms, including the reconstruction of heritage sites in 3D modeling [14, 2]. However, the use of digital heritage in VR/AR has been criticized as a method to convey meaning [15], for instance with respect to a lack of real content other than the reconstruction itself, a lack of user engagement and real sense of place. With the advent of mobile devices and ubiquitous computing, a relevant area of research has become the study of methodologies to distribute information in the real, physical space, applying geolocalization technologies [8]. Recent developments in mobile Augmented Reality [17, 13] focus on the use of spatial navigation, including physical movement in an environment, as a novel paradigm to organize the interaction with content [10, 8, 1]. In this study we present a framework that seeks to integrate a number of the key developments in the mentioned fields, combining reconstruction, on-site database access of content, and outdoor VR/AR navigation as well as information guidance, while addressing the critique of [15] and engaging information interaction together with learning [4, 6] using navigation in space. In Section 2 we present a description of our framework, its basic functionality and main structures. Section 3 discusses a first implementation of the architecture in the form of a mobile AR application for outdoor interaction with historical material placed in a virtual

reconstruction, while navigating in free or guided modes. In section 4 we present our conclusions.

1.1 Bergen-Belsen case

The platform and tablet application presented here were developed in collaboration with the Bergen-Belsen memorial in Germany, which offered us the availability of a historical outdoor environment, as well as a large amount of historical content material from the memorial's archive that refers to multiple locations in that environment. Bergen-Belsen is a former WWII concentration camp in northern Germany from which most architectural structures were burned down shortly after its liberation in april 1945 to avoid the spread of a typhus epidemic. Today, the site is a nature park hosting a number of memorial structures, mass graves, and memorial foundation buildings. Information about the camp can be found in documents, books, and a permanent exhibition in the documentation center of the Bergen-Belsen Memorial. Yet, onsite there are nearly no physical remains of the original structures, and visitors largely depend on their imagination to reconstruct the topology of the camp and connect the tragic events that took place there. Both the Bergen-Belsen Augmented Reality application and the broader framework described in this paper aim to fill this gap through the use of novel communication technologies.

2. FRAMEWORK DESCRIPTION

2.1 Overview

The platform presented in this section consists of a number of core elements that integrate into the hand-held tablet application discussed in section 3. In the following paragraphs, we introduce a platform concept applicable to more applications than that one: a geolocalized 3D virtual reconstruction that constitutes a navigable entry point to a geolocalized historical database.

2.2 Historical sources

The application database constitutes a searchable structure developed in SqlLite. It allows for the organization of and interaction with historical content items, as well as the association of these items to coordinates in the real world environment. The content of the database is constituted by historical documents in the form of digitized multimedia files. Core element in this organization are metadata-sheets, that store multiple information fields based on the documentation center's existing archive filing system. These metadata sheets provide the essential link between database search and on-site navigation. A dedicated web application was devised to facilitate the selection, addition and editing of content and metadata in the platform database by experts of the memorial foundation themselves. The web application is directly connected to the database, and therefore edits made in the web also affect how content is deployed and displayed in the client tablet application used in the field.

2.3 Virtual Reconstruction

Since the camp existed between 1938 and 1945 and its complex history includes many different uses, inhabitants, buildings as well as sub-sections, its reconstruction cannot be generated as a model of one single state, an common issue in other historical reconstruction modeling cases [15]. To address this issue, spatial items were identified in a way similar to a cadastral register. Each 3D model carry metadata storing information on its state and use relative to points in time. The 3D reconstruction that is generated and rendered from prepared models is thus composed from the momentary state of the whole of elements at the requested moment in the timeline. This database-approach prepares also for the association of content items to historical spatial items, next to their association to real-world coordinates. This approach also assesses another common issue in the practice of historical reconstructions: that of uncertain, inaccurate, ambivalent, or incomplete information [11]. In this platform application, a *Master model* is conceptually separated from its public *Exposition* derivative, the latter representing a style and level of information detail that is found suitable for the public, while the first seeks to integrate all information available — including uncertain and discussed elements. The *Master* version in the Bergen-Belsen case integrates all kinds of information, from available historical as well as current maps and geographical data, photographs, blueprints, witness descriptions and drawings. The *Master model* is therefore a model state that is essentially by default open for discussion and updating, while its *Exposition* version is an application-specific, fixed derivative of it.

2.4 Applications

Content database, spatial association via metadata, and reconstruction come together in a visual representation with which a user navigates, both in space, content, and history. Thus far, two applications have been deployed that demonstrate this integrative platform characteristic. A first prototype was implemented as immersive indoor installation at the memorial's entrance square, depicting the reconstruction on a 180 degrees screen projection as part of an introductory presentation to the memorial site and its history. This first, non-interactive application has been working since its installation in the fall of 2012 and is not further discussed in this paper. In next section, we describe the hand-held implementation of the platform.

3. HAND-HELD APLICATION

3.1 Overview

The application described here integrates database interaction, reconstruction modeling and content presentation in a hand-held device following an Augmented Reality paradigm to be used by visitors on-site. iPads were chosen as tablet hardware, and most software was implemented using the multi-platform Game Engine Unity3D[1], which offers state-of-the art possibilities for 2D and 3D graphics visualization.

3.2 Database implementation

A limited amount of archive content was selected by the memorial's history and education colleagues and submitted to the platform's database structure. Metadata for these items was also entered for 30 fields, of which the 4 most important ones, (title, author, description, and reference) are currently applied in the on-site interaction. Origin and reference locations were entered and made available using the dedicated web application of the database.

[1]www.Unity3D.com

3.3 Reconstruction implementation

The reconstructed states of the former camp site were limited to two moments in its history: September 1944, and April 1945. The reconstruction of the two states was performed by integrating a body of research by the memorial experts themselves, together with several maps, photographs, drawings and descriptions into master model files. 3D modeling was based on the integration of information in blueprints, photographs, drawings and descriptions, and performed using programs Autodesk Maya[2] and Sketchup[3] (Fig. 1). Available maps were matched to geodesically corrected and combined historical aerial photographs [16, 9] as well as the present day satellite imagery used for the tablet's global positioning system (GPS). The generated master maps describe buildings, fences and other spatial objects and areas as vector objects that can at all times be compared to historical source layers. The vector master maps subsequently served to place and size 3D models as accurate as historical sources and expert interpretation could offer, and construct the geolocalized virtual environment (Fig. 2) The represented model style developed from a initial estimate-photorealism to a deliberately minimal, desaturated and more abstract style. The reconstruction was equalized to a basic level of plausible form, avoiding the invocation of a immersive experience based on speculation. Differences and uncertainties were discussed and solved in close collaboration with the memorial's experts.

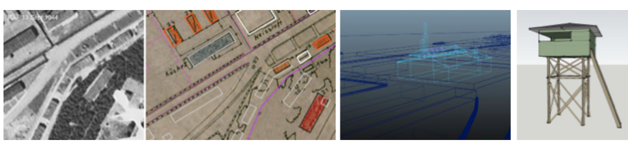

Figure 1: From left to right: 1944 aerial photograph of the camp (IWM London), 1943 presumed building plan by Heeresbauamt, virtual model of Delousing building and final version of an outside fence watchtower.

3.4 Sensors

The video stream (1920x1080) from the iPad's in-built camera, the in-built GPS, compass, and gyroscope sensors of the iPad are used as inputs to the Unity application. GPS uses a refresh rate of 200 milliseconds and has an accuracy of around 2-3 meters. Compass is used to recalibrate Gyroscope and align the virtual environment with real cardinal points.

3.5 User Interface

The application offers two view modes to navigate space and content: Map, and Field view (Fig. 3). In both cases, the shown state of the reconstructed site is made dependent on the chosen historical period. Map view offers an overview of the entire area as well as the historical sections of the former camp. Subjective to choice, the map can be made to rotate automatically to align with North (egocentric navigation), or to remain fixed independent of the user's position and angle (allocentric navigation). Field view offers a look on the site from an average-height 1st-person perspective, showing buildings, fences and other objects in a 3D projection. As

Figure 2: Through the hand-held device, user can see virtual reconstruction placed in real world coordinates.

virtual camera orientation is mapped to the sensors of the tablet, users need to physically turn in order to change the view within the reconstruction. In Field View mode, Virtual and Augmented reality modes are available, the latter offering to superimpose the reconstructed building and fence models on the iPad's camera image, effectively comparing past and present states.

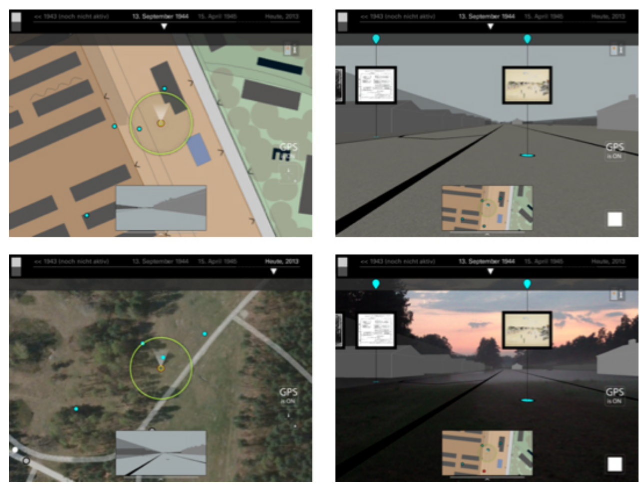

Figure 3: Four different views at the same location. Top left: Map View showing a 1944 state. Bottom left: Current day Map View with POCs. Top right: Virtual Reality Field View with available POCs previews. Bottom right: Augmented Reality superposition on the local camera view.

3.6 Content placement and presentation

As a first step towards situated historical content sequencing, content presentation was disassociated from offering total availability. In the main platform concept, points of content (POCs) are hidden and revealed under controllable conditions, to facilitate different kinds of content interaction in an environment. To further dissociate reference locations of content from presentation locations in the environment, POCs were grouped to Points of Interest (POIs). In this manner, sets of content can be grouped, for instance thematically or topographically, and made available from positions other than the content's actual placement. The latter possibility offers an important control on the user's required position in the outdoor, partly forested environment. Two modes were implemented for the presentation and assess-

[2] www.autodesk.com

[3] www.sketchup.com

ment of POIs: Free, and Guided exploration. In the Free mode, all POIs are made visible to a user in the environment, but the associated content items can only be assessed when one is near enough. This proximity condition is implemented and communicated using a wider circle around the user's locator on the map. In the Guided exploration mode, not all POIs are made visible at the start, but they are revealed stepwise, with the same proximity condition applying after points became visible.

POCs as well as POIs communicate the different state of availability (e.g. Sleeping / Calling / Active / Visited) by color changes of the marker icons visible on the Map and Field View. In the latter, the user is assisted to find these points by a top bar that indicate their position in the 3D space through a dynamic GUI element. If a POC is active, meaning that its content is available, a preview window of the content is presented that can be clicked to open the content (Fig.4 left). A full screen mode makes the content available to the user, revealing also its caption sheet containing metadata information (Fig. 4 right). This sheet can be slided aside to have a clear view of the content alone.

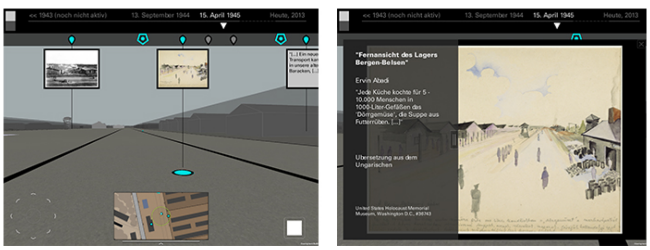

Figure 4: Left: Content Preview in Field Mode. Right: full screen content visualization with removable caption overlay.

4. CONCLUSIONS

We have presented a platform solution to enhance public heritage experiences by the integration of historical database content, environment reconstruction, and navigation in outdoor environments. We introduced the first deployment of this platform in the Bergen-Belsen Augmented Reality application: a mobile, on-site, guide/companion tool for the geolocalization, visualization and exploration of historical data. We believe the spatialization of experience and content that the framework allows will facilitate the understanding of complex historical datasets and the generation of more meaningful experiences in cultural heritage contexts. The first version of the application is currently being tested with public in the Bergen-Belsen memorial's landscape environment. We plan to report the results of this process soon.

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