A virtual diorama

Mapping archives *in situ* at places of cultural significance

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Abstract: *Using the wooden church of Södra Råda as a case study, this article concerns new applications of technology to contextualise and activate archive material in situ at places of cultural significance. Using a combination of augmented reality and virtual reality, we describe a process of turning historical photographs and two-dimensional reconstruction drawings into three-dimensional virtual models that can be lined up to a physical space. The leading questions for our investigation concern how archive material can be contextualised, and how the result may be made accessible in situ and contribute to place development. The result of this research suggests possibilities for using historical photographs to faithfully reconstruct lost historical spaces as three-dimensional surfaces that contextualise documentation and offer spatial information.*

Keywords: Virtual reality, augmented reality, diorama, archive, technology, context.

The archive is often considered to be a repository of the past, a collection of material pertaining to an era, a place, occurrence, person or community, that could be probed and questioned but should not be disturbed. However, as philosopher Jacques Derrida notes, archives are not created to serve the past, but instead the *future*: What uses can be drawn from our documentation and how can it be activated to bridge the present state and the past to advance our knowledge (Derrida 1995)? However, in many cases, not least so when it comes to historical documentation, the documents of the archive are divorced from their physical place of origin and that which they represent. This article concerns new applications of technology to contextualise

and activate archive material *in situ* at places of cultural significance. As such, it focuses on the results of an explorative study where historical photographs and two-dimensional reconstruction drawings were activated by being processed into three-dimensional virtual models and then mapped onto a physical space using a combination of augmented reality and virtual reality. As a case study, we have worked with various processes of the reconstruction of the wooden church of Södra Råda, which was burned to the ground in 2001 by an act of arson (fig. 1). The church was one of approximately twelve medieval log timber churches still preserved in Scandinavia, and was recognised foremost for its distinctive wall paintings, making it an important destination

Fig. 1. Historical photo of the church of Södra Råda. Photo: ATA, photographer and date unknown. CCPD, ATA Riksantikvarieämbetet.

point for tourism in the region. By the late nineteenth century the church had already been deconsecrated and transformed from a place of worship into a heritage museum. As such the building continued to serve the local community for events like concerts, weddings, and baptisms. Being an important node in the local community, the National Heritage Board took a decision that the church should be reconstructed as a pedagogical example to enhance craft practice and historical knowledge of medieval churches.

The full-scale reconstruction of the timber building now being erected on the site focuses on the potential benefits of advancing research and developing skills in historical woodcraft procedures. As the project is nearing completion, the stakeholders have raised the question of what will happen to the physical

reconstruction and what will activate this place when the attraction of the reconstruction effort comes to an end. There is a saying among children that applies here: “It’s more fun to build the hut than to play in it.”

Arguing that reconstructions have a valid place in heritage management, archaeologist and historian Neil Silberman writes that

when based on adequate research – in addition to the documented testimony of tradition bearers – reconstructed buildings can provide an immersive, multisensory environment in which visitors [...] can acquire a heightened understanding of local culture and a more palpable sense of the place and of its past (Silberman 2015:5).

Hence, the reconstruction is seen as a tool through which to overcome, or perhaps mend,

rifts in the cultural continuity of a place, and can as such be used to encourage the public to value heritage rather than just “sanctifying original fabric” (Silberman 2015: 5). Silberman argues that reconstruction is not a conservation approach but rather “an engagement approach that can help reconnect people with place, history and landscape” (Silberman 2015:5). However, at its core, the reconstruction needs to be based on careful and well-documented research. According to Silberman, the credibility, or the reliability, of the reconstruction is thereby an important asset upon which the positive engagement, the reconnection to place, rests.

The title of the article refers to the traditional museum *diorama* in which artefacts or specimens are mixed with artificial constructions and matte painting to create a scene that communicates a context within the confinements of a display. The diorama is neither the specimen nor the background, but the hybrid of these that situates the specimen, making it inseparable from a context. Dioramas are not limited to displays that one looks into from the outside, but could be immersive experiences when combined with a cyclorama – a huge panoramic matte painting surrounding the visitor – or when presented as a delimited space reconstructed from both artefacts and new constructions. However, like the Atlanta Cyclorama from 1886 reconstructing the Civil War Battle of Atlanta, the former seldom incorporate full scale or authentic artefacts in their associated dioramas. The latter, in contrast, are often full-scale scenes of interior spaces, such as The Country Church at the Historical Museum in Stockholm, where artefacts have been arranged as part of a room-scale reconstruction.

Through the concept of diorama, we align ourselves with a well-established practice and theorisation within museology (see Hägerstrand

1997, Bengtsson Melin 2014). In our use, the virtual diorama is a technique through which to contextualise an artefact or milieu by bringing it together with digital representations of materiality that have been lost or removed. This entails a documentation process where surviving artefacts are inventoried and scanned. The documentation is then assembled in a virtual 3D space matched up to a physical place. Hence, like the traditional diorama, artefacts are displayed through a visual narration of context. The final physical reconstruction of Södra Råda church will be of bare timber, which means that the interior wall paintings, an important characteristic of the church, will not be reconstructed. To mitigate this, and bring context to the reconstructed space, the research seeks feasible ways to combine the physical reconstruction with digital layers that let present and future visitors experience the wholeness of this exquisite architecture.

RESEARCH AIM

Södra Råda was one of the best-documented buildings in Sweden, and the bulk of the archival material concerns the interior wall paintings. The Heritage Board’s archive preserves over a thousand original photos of the interior from various decades of the last century. Furthermore, in 2007, the Heritage Board published an illustrative volume with reconstructions of the chancel paintings by conservator Hans Peter Hedlund done in conjunction with a paint conservation action in 1995. The leading questions for our investigation concern how such historical photographs can be processed, contextualised, and used as analytical visualisations by being translated into virtual models, and how the result may be made accessible *in situ* and contribute to place development. The research

Fig. 2. The richly decorated interiors of Södra Råda church. Photo: ATA, photographer unknown, 1908. CCPD, ATA Riksantikvarieämbetet.

has focused so far on the historical timber construction and craftsmanship, but an urgent need for the future management of the site is how to visualise and communicate the brightly coloured lime paintings that covered the walls and wooden trefoil vaults in both nave and chancel once constituting the primary cultural historical value of the church (fig. 2). The total painted area covers more than five hundred square meters of narrative religious scenes. According to an inscription, the chapel paintings date to 1323. The paintings were dedicated to the Virgin Mary and depicted her death, ascension, and coronation. This suite of Virgin Mary was considered the most

distinctive and artistically refined in all of Swedish architectural painting (Ullén 1979). The painter is unknown but the style associates to the French illustrated bibles and devotional tracts that were common and widely spread in early fourteenth century (Hedlund 2007). Characteristic is the depiction of architectural features, the picturesque character of coloured or patterned backgrounds, and the wordless banners. They used blue azurite, green malachite, and red vermillion, but it was the last of these that was preserved throughout the centuries, described by the Swedish art historian Bengt Söderberg “as if painted in fresh strawberry juice” (Söderberg 1951).

In this study we have investigated a method of processing the archival material depicting these lime paintings into a spatial reconstruction that can digitally be mapped on top of the bare timber of the reconstructed chancel. Our method involves the manual modelling of a virtual backdrop from the measurements in survey drawings onto which we project textures derived from the archival material. The backdrop has then been activated using an augmented reality (AR) platform to establish a relation between the visualisation and the physical reconstruction of the church of Södra Råda, and a virtual reality (VR) platform to present the archive material of the historical wall paintings.

While visualisations, 3D models, and prototypes have found prominent use in humanities research (Mahony & Boddard 2010:7, Westin & Eriksson 2010, Madsen & Madsen 2013, Nygren, Foka & Buckland 2015), and have facilitated critical discussions on the application of digital tools in the context of museology or the narratives of digital heritage (Liestøl 2011), there are still a number of use cases to explore and evaluate in the field of heritage management and conservation science. Our study, which draws on recent projects and research in the digital humanities, virtual archaeology, museology and heritage studies (Imitatio Maria at HumLab in Umeå, Via Appia project at Amsterdam university, Pompeii project at HumLab in Lund, CHES project at New Acropolis Museum, MATRIX project at Michigan State University), serves to both assess and inform emerging perspectives on the uses of technological tools in cultural heritage display, education, and humanistic research. While several ongoing projects are either making use of sophisticated scanning techniques of objects and entire sites (Forte *et al.* 2013, Heuberger *et al.* 2015, Zhang *et al.*

Fig. 3. The unadorned virtual projection surface. Model by Jonathan Westin and Gunnar Almevik.

2015) or bringing access to the digitally obtained or modelled material through various interfaces (Cecconello & Spallazzo 2010, Ghadban *et al.* 2013), these almost exclusively use the technology to separate the documentation from the physical site.

A VIRTUAL BACKDROP WITH TEXTURES FROM HISTORICAL PHOTOGRAPHS AND DRAWINGS

Södra Råda is located in the town of Gullspång, which is in Värmland County and the administrative region of Västra Götaland. In 1858 a new stone church was built in the parish, and the old wooden church was taken out of use. The church had a log-timbered structure dating to about 1309, which at the time was one of the few oldest existing church buildings in the world with log timber structure and corner joints. The log timber construction had a total length of sixteen meters with a 10.6 x 8.5 m nave and 5.3 x 5.6 m chancel. The steeply pitched roof occupied half of the building's height and reached twelve meters above the ground.

The interior church space was distinctive not only for the extensive paintings but for its inner trefoil vaults made of wood. While it is possible to obtain a 3D model of Södra Råda from analogue historical photography using Structure-from-Motion (SfM), individual sets of photographs from specific photographers or collections of photographs that document the appearance of the church in a certain year or decade have proven too delimited to produce any reliable result (Almevik & Westin 2017). Furthermore, alternative visual documentations, such as reconstruction drawings, cannot be processed through SfM. In response to this, a virtual projection surface, what we call a backdrop, was modelled after the chancel interior architecture in Strata Studio CX7. Since the historical construction of Södra

Råda was systematically surveyed in 1908–09 by Ragnar Hjorth and Carl Nyqvist at the Royal Superintendent's Office, and Gunnar Wirsén at the National Heritage Board further documented the building in 1982–83, exact dimensions could be obtained.

To function as a backdrop onto which to project the two-dimensional archival documentation, the unadorned 3D model based on these documentations was modelled using the barest minimum of polygons to describe the inner walls of the chancel, thus avoiding structural details and depth beyond the curvature of the vaulted ceiling and the direction of the walls. This approach, resulting in a model akin to a structure made of folded paper, played to the idea of putting the archival documentation front and centre, where the

Fig. 4. The UV maps of the vaulted ceiling and the four walls. Drawings by Hans Peter Hedlund.

Fig. 5. The rectified reconstruction drawings and historical photographs projected onto the backdrop using UV maps. View towards the east wall. Model by Jonathan Westin and Gunnar Almevik, drawings by Hans Peter Hedlund, and photographs by Marianne Bratt Gustafsson and Gabriel Hildebrandt.

structure is just a canvas for the drawings and photographs (fig. 3). To map the two-dimensional material onto this backdrop, the model was used to render six unique UV maps of the geometry, one for each wall and two for the vaulted ceiling. A UV map is like the sheet of an unfolded box on which the surfaces of a 3D model are presented in 2D space.

Using an SfM model as a rough reference

in conjunction with the measurements taken during the paint conservation work of 1995, Hans Peter Hedlund's reconstruction drawings from 1995 were inserted into the UV map as a guide for two sets of archival photographs (fig. 4): black and white 35 mm photographs by Marianne Bratt Gustafsson shot in 1959 and colour slide images by Gabriel Hildebrandt shot in 1992. Both Hildebrandt and Bratt

Gustafsson were professional photographers at the National Heritage Board. The archival photos were then analysed and grouped according to the photo set to which they belong and the boundaries of the architectural surface in the UV map. The selected photos were stitched together in Photoshop CC 2016 by the automatic merge procedure. If an image could not be merged by the automated procedure it was later manually cut and pasted into the UV map.

While this procedure resulted in large sheets of stitched-together photos, these needed to be warped to fit the boundaries of the UV map and the distortion caused by the vaulted roof. To correctly rectify the photo sheets we used the already rectified reconstruction drawings by Hedlund. The photo sheets were put in semi transparent layers on top of Hedlund's drawings, and then warped to fit these using the Photoshop tools Free Transform, Warp, and Puppet Warp. Finally, the layered document was used to export several sets of UV maps as high-resolution images; one for only the reconstruction drawings and one for each rectified photoset with outlines of the reconstruction drawing filling out the lacunas (fig. 5).

BRINGING THE ARCHIVE BACK TO THE CHANCEL

There is a growing list of projects where AR is utilised to bring digitised or born digital material to a physical site (Martinez *et al.* 2015, Canciani *et al.* 2016, Kasapakis *et al.* 2016, Zikas *et al.* 2016). AR is primarily associated with layering place-specific visual information on top of a live video feed obtained through a smartphone or tablet computer to augment the vision of reality. By creating a marker recognisable to the software, the software

can then overlay information in relation to said marker when recognising it through the device's camera. However, AR does not require a screen as the underlying concept of the technology can be delivered just as effectively through audio (see Kahr-Højland 2007, Poole 2017), something that has been realised through audio guides at museums for half a century (Proctor 2009).

Using AR as a visualisation tool in historical disciplines, virtual artefacts or monuments can visually be placed in the physical world in real time. This has several advantages as it is not limited to the contextualisation of scale, shape, and colour that traditional photography-based reconstructions can convey (Cohen 1985, Frizell & Westin 2009): In addition to being three-dimensional, the virtual AR object can be made interactive and thus be virtually manipulated and studied in different ways while both protecting the physical artefact and being displayed in its natural context (Santos 2012:13).

However, marker-based AR is primarily functional in scenarios where the device through which the AR overlay is projected is either fixed at a certain distance and angle, or allowed to circle the marker and present an object from the outside. In the case of the chancel of Södra Råda, the virtual backdrop would need to surround the person holding the device, effectively placing the person inside the augmented reality scene, which makes tracking by markers difficult if not impossible as the visual connection between device and marker must be maintained. Using a visual-inertial odometry tracking system, such as Apple's ARKit (based on technology developed by Metaio), or Simultaneous Localisation And Mapping (SLAM), sidesteps the use of markers as all horizontal surfaces in a space are mapped in 3D. Essentially this creates a large amount

of markers all around the device in 3D space, which are continuously tracked and compared with motion detecting data. However, while these technologies allow for well-anchored and immersive AR content to be displayed, they are not place-specific they way marker-based solutions are. For place-specific markerless content, AR and Virtual Reality (VR) can make use of external sensors to track the movement of the device creating an outside-in system for position tracking. These are mainly based on commercial camera-based motion capture systems, such as Vicon, Optitrack, Openstage and Microsoft Kinect (see Younes *et al.* 2016). However, even the less advanced indoor positioning systems (IPS) based on iBeacons or wifi-triangulation, which only roughly track the position of the device, come with both deployment and maintenance costs. To design a solution that would be both cost effective and easy to deploy and maintain, we explored a hybrid solution using an AR platform (Vuforia) in conjunction with a VR implementation (GoogleVR).

VR is a broad term, and there is great variation in the proposed definitions (see Guttentag 2010). Here we define VR as the presentation of a Virtual Environment (VE) from a first-person perspective, where the point-of-view, the viewport, is updated as to follow the natural movements of a person in real-time, thus lending a tangible connection between the physical movements of the user and the VE. When presented through a handheld device rather than a head mounted display, as we opted for in our implementation, the effect is akin to holding a small portal through which one can peek into the VE. To create a VE containing the virtual backdrop of the chancel, and match it to the physical position and orientation of the person holding the device, we used Unity. Though primarily

being presented as a game engine, Unity has seen wide adaptation as a research-driven visualisation tool.

However, without outer sensors, the VR view will always use the same x-axis direction as point of origin, no matter the direction of the device. Hence, if the VR camera in the VE is facing east but the device is facing south when the application is started, there will be a mismatch between the physical and the virtual environment (fig. 6). To overcome this limitation, we created a mixed reality application that a) makes use of AR to calibrate the direction of the handheld device and the VE, and b) transitions to a VR scene when the calibration is done. Though presenting a three-dimensional full frame VR scene and not a hybrid which combines reality with an information overlay, this solution is closely related to what Wither, Tsay & Azuma calls Indirect AR (2011). Indirect AR, in their definition, serves up a pre-annotated panorama image of the surroundings, thus creating a stable relation between the information overlay and the captured vision of the surroundings. As the augmentation of information is not live matched to physical reality this avoids any tracking problems (Wither, Tsay & Azuma 2011:810). As a technique it is also applicable to Situated Simulations, which usually employs real time rendered 3D scenes (see Liestøl 2014). However, Indirect AR does not solve the problem of automatically matching up the panorama with the surroundings, but often rely on manual interaction such as touch-dragging the virtual setting (see Madsen & Madsen 2013).

Our solution entailed using Vuforia, an AR SDK from Qualcomm, to create a marker based on the outer bezel of the east facing window frame in the chancel. This marker was then imported into Unity. Two scenes, which

Fig. 6. The physical (unbroken line) and the virtual environment (dotted line) not matching up, thus breaking the illusion of a connection between the two. Illustration by Jonathan Westin.

in Unity are organisational units, were created; one with the AR marker (hereafter Scene One), and one with the virtual backdrop (hereafter Scene Two). In Scene Two, the virtual backdrop was textured with the UV maps created from the drawings by Hedlund. The UV maps stitched together from the photos by Hildebrandt and Bratt Gustafsson were also imported but were at this point not used as textures. A camera was placed in the centre of the virtual backdrop, and turned facing the east window. This camera was connected to the Inertial Measurement Unit (IMUs) of the handheld device through the GoogleVR SDK which allowed it to perform rotational tracking and manage orientation changes.

In Scene One an AR camera was placed and trained to recognise the AR marker corresponding to the east facing window. This allowed us to serve up an invisible event

trigger reacting to when the device is pointed towards the AR marker. This trigger is in turn connected with a script that transitions the view to Scene Two and initiates the VR camera if the device has been focused on the south window for more than two seconds. During these two seconds, visual cues are presented to the user as an incentive to keep the device focused on the window. This setup, together with a circular marker centrally placed on the floor, marking the best place to experience the VE, allows us to predict the position of the device (centrally in the room), and make sure it is lined up with the direction of the VR camera (the east facing window) for the transition to the VE in Scene Two.

Due to the lack of positional tracking to reflect translational movements of the device, a feature that modern, desktop VR solutions are able to provide by utilising external cameras trained on the headset, the user is required to keep within the centre of the room for the relation between VE and physical space to be maintained. While this is a serious limitation that motivates further research into cost effective solutions using either inside-out or outside-in sensors such as iBeacons or cameras (see Zikas 2016), in this case it is mitigated by the use of handheld VR, forgiving as it is. As Wither, Tray & Azuma write, drawing comparison to a camera, though the viewfinder presents a view modified by the lens system and is not an unmediated and transparent view of the world, the bezel around the screen helps over bridge the two visions (2011:810). Furthermore, the very context of Södra Råda constitutes a mitigating circumstance: churches, such as Sant Ignazio in Rome, Santa Maria presso San Satiro in Milan or the Old Whaling church in Edgartown, have a history of making use of interior pictorial decoration carried out in perspective to create a false depth

Fig. 7. The archive photos explored through a Virtual Reality view lined up to the physical chancel at the site of Södra Råda. Photograph by Gunnar Almevik.

to the architecture, a technique that hark back to the advent of the Second Pompeian Style. In these churches, there are often a circular marking on the floor indicating the optimal position from which to experience the *trompe l'oeil*.

Since each photo-set had been processed into a unique UV map, these were made interchangeable to allow the visitor to switch between them by tapping the virtual projection. Hence, as an overlay on the unadorned physical reconstruction, the historical documentation is brought back not only to the site of origin but also to the precise position, contextualising not only the physical space but also the archival material (fig. 7).

DISCUSSION

In the nineteenth century, at a time when traditional scientific illustration was becoming increasingly abstract and restrained in style, the reconstruction drawing, at first in the fields of palaeontology and geology but soon thereafter in prehistoric archaeology as well, gained ground as an unparalleled technique to lend life and context to scientific findings (Moser 1998). The diorama, a three-dimensional equivalent of the reconstruction drawing, was during this era adopted by museums of natural history as a tool through which to create a mixed reality where specimens and constructed sceneries were brought together. This article has presented working techniques

using AR and VR for transforming archival material into models that bring life and context both to the material and to a physical space by bringing them together. The result of this research suggests possibilities for using historical photographs to faithfully reconstruct lost historical spaces as three-dimensional surfaces that contextualise documentation and offer spatial information.

By establishing a virtual backdrop onto which several different texture sets, as UV maps, can be projected, the material could be contextualised manually. It is thus possible to systematically process the archive of images and keep the different sources separate. Since the photographs on a UV map do not need to overlap, or even be connected, all unique photographs in an archive could potentially be used. Even if a series of historical photographs fails to cover all details, leaving patches uncovered, these lacunas could either be emphasised or filled with other types of visual documentation such as reconstruction drawings. With a manually constructed 3D model one is free to expand the structure beyond what is covered by the available photographs. Furthermore, as the virtual backdrop does not contain any depth or details beyond a smooth surface, the end result is low on polygons and thus scalable to a number of mobile platforms.

The working procedure through which to connect and contextualise archival material *in situ* at places of cultural significance presented in this article have a wide scope in the field of cultural heritage conservation and management, as well as cultural tourism. Considerable growth can be expected in the coming years as technology becomes more accessible, making possible new forms of knowledge and novel insights of various aspects of both the built environment and

human life (Schriebman, Siemens & Unsworth 2004, Drucker 2011). In parallel with the increased scholarly production within the field, an effect of imaging technologies becoming more affordable, and spurred on by the nearly ubiquitous presence of smartphones and high-speed internet access, heritage institutions are increasingly embracing technological solutions. As anthropologist Graeme Were writes, “The ‘recoding’ of culture to its digital counterpart thereby signals a significant shift towards a new kind of heritage experience, one that is marked by heightened mobility, on-demand availability and virtuality” (Were 2015:153). Presently the prototype application has only been used on site by a limited group of test persons on an equally limited number of devices. Future challenges include enticing a visitor to download the application onto her device, and, unguided, discover the functions. For this process to feel obvious, heritage sites and monuments must start to be seen as the natural inroad to archival information.

The legitimacy of cultural heritage sciences grows in a situation where the research ensures sustainability and provides knowledge of objects that people value as cultural heritage. While collections of historical photographs are a rich source of information, the information stored in archives is often fragmented and inaccessible to the stakeholders of cultural heritage. Just as the diorama is a hybrid in which an artefact and its backdrop charge each other with meaning, the archival photos and reconstruction drawings come alive when given a spatial context. The 3D model becomes a diorama both in its own right, as it lends context to each individual photo in the archive, and in communication with the physical reconstruction. Furthermore, by being displayed *in situ* at the reconstruction of Södra Råda, the archive is *activated* as a

narrative device that lends history and context to the reconstructed space; the photographs and the drawings tie the reconstructed church together with the church that burned, bridging the distance between them, and the individual scenes in the painted roof and walls can be read in their original setting.

This is of great importance for the awareness of our cultural heritage, since it is context that brings meaning. Mapping the virtual reconstructions and documentation to the physical reconstruction may re-establish a momentary *thereness*, a “presence effect” in the words of literary theorist Ulrich Gumbrecht, in which the visitor experiences not only the remains but also the space as it once was (Gumbrecht 2004:79). VR in conjunction with AR provides new opportunities to assemble and contextualise the archival information in direct relation to the tangible cultural object, whether reconstructed or not, and thereby increase the knowledge-based perception and valuation.

ACKNOWLEDGEMENTS

We wish to acknowledge the staff at National Heritage Board’s Archive and their help with the historic photographs of Södra Råda. Jonathan Westin is funded by the Södra Råda Trust and part of the experimental research project linked to the reconstruction of the timber church in Södra Råda. This article is also part of Gunnar Almevik’s research fellowship at the Royal Swedish Academy of Letters, History and Antiquities and the research project Wooden Building Culture. Finally, we would like to thank our anonymous peer reviewer who offered many insightful and constructive comments on our original manuscript, which helped us refine our arguments.

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