Projected Time Travel:

Architectural Heritage Projection in Situ

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Abstract: Aside of architectural heritage that is readily visible to the public like well-known tourist sites, there are many heritage objects which only exist in restricted excavation sites or in museums to where they have been moved. Some of them exist in literature only. Archaeologists put a lot of effort into the reconstruction of architectural heritage, even in digital form. Still, most of this work is hardly ever shown to the public in its original size. We advocate the public visibility of architectural heritage in its digital form.
For a convincing display we suggest a nightly projection in situ, showing the virtual reconstructions in their original place. In order to achieve this form of projection, we address the challenge to project over existing architecture taking the uneven and textured projection surface of the existing architecture into account. This will be achieved through a projection mapping technique, correcting the geometric distortion as well as the texture variation of the naturally uneven projection environment. As a result of this work we aim at a nightly projection of a virtual reconstruction of past times for the public to enjoy. With this approach a virtual time travel through different epochs is possible and made visible. The innovative technique of this approach lies in its mixed reality visualisation of architectural heritage: the (virtual) past is projected over the present in its original location.

Keywords: Architectural Heritage, Projection Mapping, Mixed Reality

The Architectural Heritage Site of Castle Waldenfels

Fig. 1 – Castle Waldenfels in Upper Austria

Castle Waldenfels was originally built as a medieval fortified castle and first mentioned in a document in 1380. In 1580 it was turned into a renaissance castle. After changing its holder several times, count Konstantin Grundemann acquired the castle in 1636, and it remained family property since then.
The current owner Dominik Grundemann opened the castle for public access, allowing diverse activities to take place inside and around the castle. This includes weddings, guided tours, concerts, seminars and an archery range.
To extend the activities with nightly events and explore new possibilities for presentation, projection mapping was chosen to augment the existing environment with new content. In the discussion process with the owner the following topics were identified to be suitable for this new technology:

- showing past structures
- showing structures not accessible for visitors
- creating thematic presentations (e.g. count Dracula and relatives)

Augmented Architecture

As a special domain of virtual architecture, augmented architecture creates spatial illusions where computer-generated views of virtual 3D structures are superimposed onto physical architecture. One useful technology in that area is known as (video) projection mapping. In projection mapping almost any surface can be turned into a video display by warping and masking the projected image to fit on irregularly shaped objects. In case of textured surfaces the projection needs additional colour correction to compensate for the colour variations on the display area.

Fig. 2 – Cultural heritage as projection media (Karlskirche, Vienna)

Some aspects of this technology have already been applied in the areas of events and advertising by skilled VJs. A recent example of commercial use was the Intel Ultrabook Promotion (INTEL 2012), where the cultural heritage site of Vienna's Karlskirche was used as a projection media that was digitally altered by projected illusions (figure 2). For the outdoor projection a large range of video projectors (figure 3) were used so that the entire façade was covered.

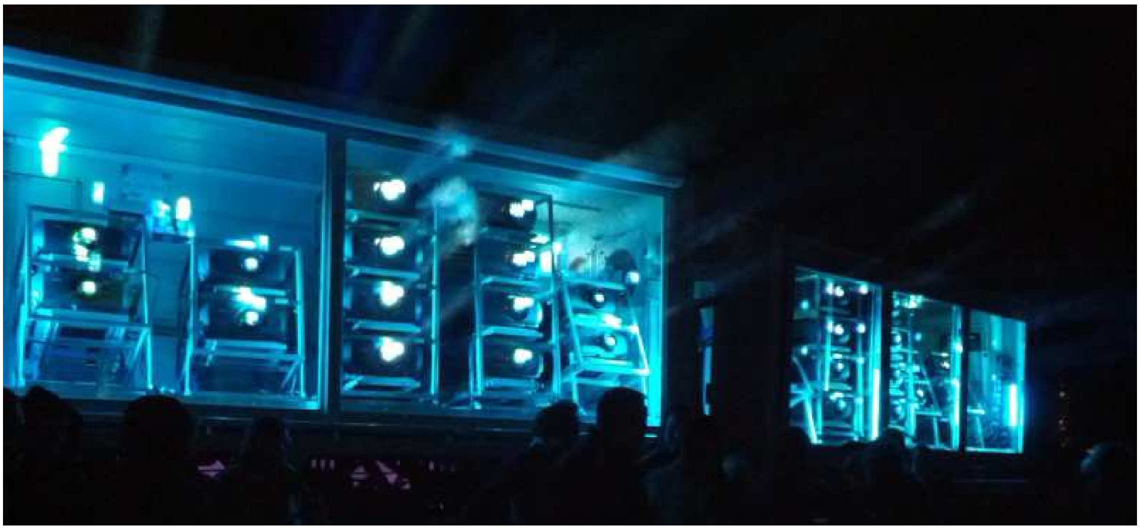

Fig. 3 –Technical equipment for outdoor projection

In the context of history, VIOSO created a mixed reality experience of past events onto the heritage site of Castle Altena in Germany (VIOSO 2009).

Challenges of Projection Mapping

Traditionally a video is projected onto a flat rectangular homogenously white surface. Ideally the projection device is mounted orthogonally to the display surface at a certain distance that enables a high quality projection of a rectangular image. Arbitrary physical shapes as display areas, however, are non-flat and textured. They can have several distinct non-rectangular coloured surfaces. Furthermore, the projector is not necessarily mounted in an orthogonal orientation towards the projection surfaces.

First ideas for this kind of video projection technique were formulated in (RASKAR et. al. 2001). The corresponding theoretical framework was laid out in (BIMBER and RASKAR 2005), referred to as "spatial augmented reality".

Projecting an image onto arbitrary physical shapes creates several technical challenges which are demonstrated in figure 4. In order to compensate for the distortions in the projected image, several corrections have to be calculated. To address the geometrical corrections, a combination of keystone correction, geometry distortion, and image masking is required. Additionally, the colour distortion necessitates a correction image to compensate for the colour variation on the projection surface.

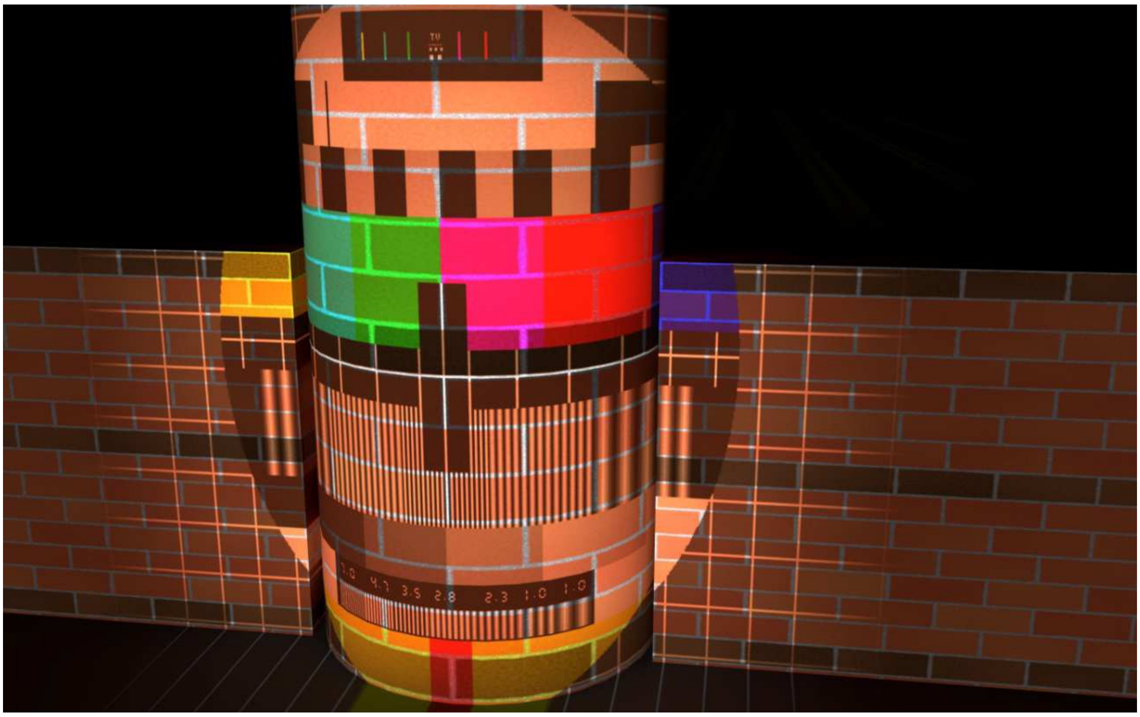

Fig. 4 – Textured display surfaces with irregular shapes

In many commercial installations pre-recorded video sequences are projected which allow for pre-processing the required corrections. For an interactive display however, the corrections have to be performed in real-time.

Technical Infrastructure

Our experimental setting consisted of the following hardware components: a laptop, a standard office beamer, and a digital single lens reflex camera. The central tower of castle Waldenfels (figure 5) served as a projection surface. The projection system was mounted at a window almost opposite of the tower, as shown in figure 6.

As a software development framework Unity3D was used. All correcting calculations were attached to the virtual camera system in Unity3D, thus enabling to project any virtual 3D scene that was created in Unity3D. The keystone correction was performed by implementing according scripts attached to the camera, masking was done using the corresponding image effects in Unity3D, and the color correction was implemented as a custom shader on the GPU.

Technical Workflow

Before the projection of a 3D environment onto the castle’s tower could be realised, a configuration phase was necessary. Figure 7 demonstrates the technical workflow.

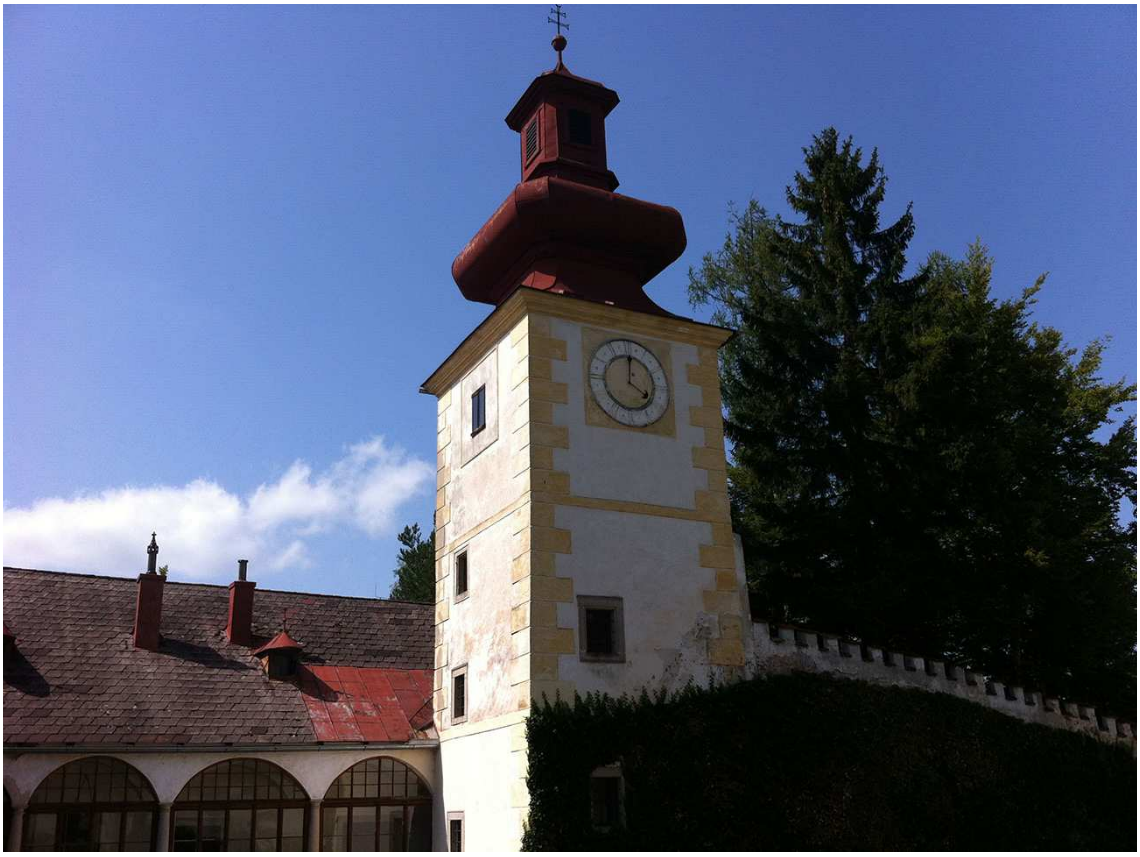

Fig. 5 – Central tower of castle Waldenfels, used as projection surface

Fig. 6 – Projection set up with laptop, beamer and digital camera

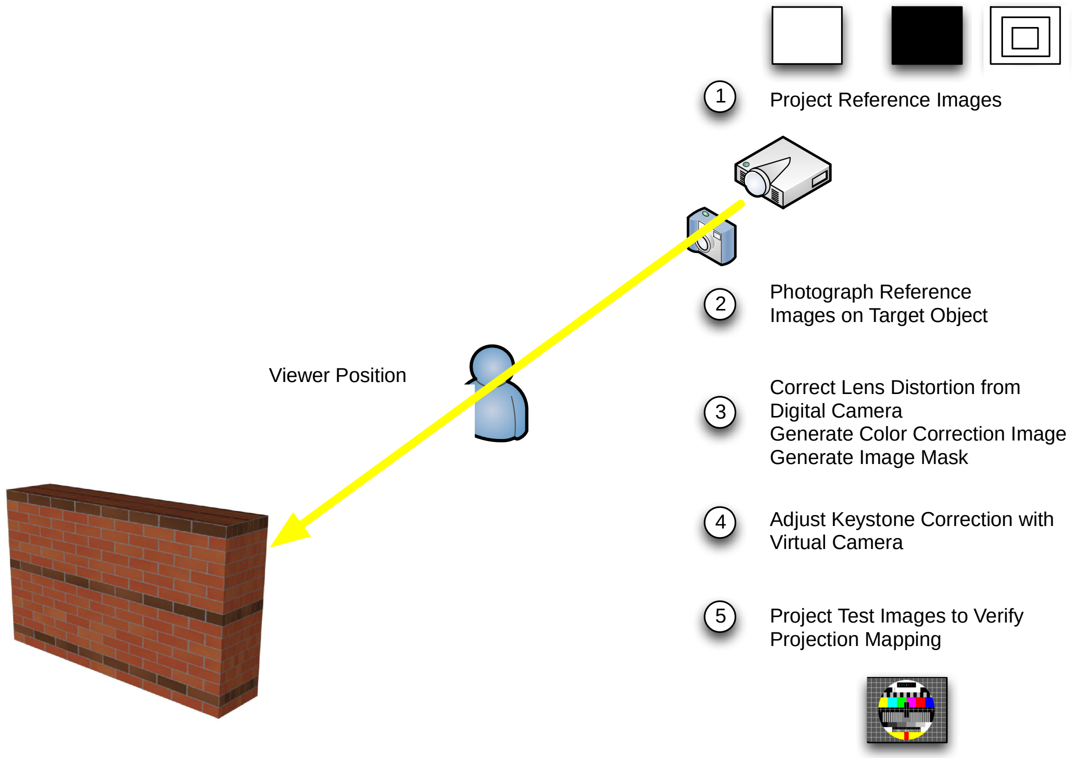

Fig. 7 – Technical workflow

As a first step, three reference images are projected onto the target surface. In step 2, each of the test images is photographed with the digital camera which should be mounted along the line of projection (indicated by the yellow line in figure 7). Additionally, a white reference image is photographed together with a white surface (e.g. sheet of paper) mounted on the projection area as shown in figure 8, to calculate the white balance of the correction images.

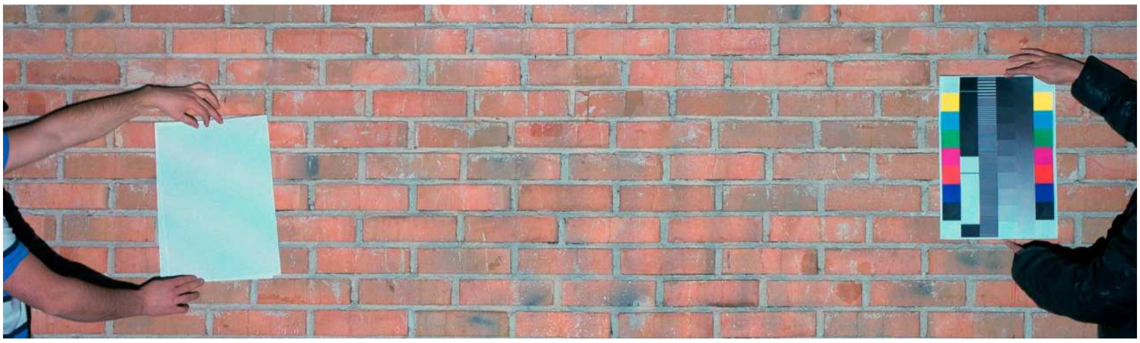

Fig. 8 – Images used for white balance compensation.

In step 3 of the workflow, the photographed images are used to calculate corrections. In order to achieve these calculations, the images themselves have to be warped to compensate for the camera's lense distortion. From the test images the mask for the non-rectangular projection area is calculated, as well as the color correction image.

In step 4 the required keystone correction can be interactively adjusted by moving the virtual camera in Unity3D. Finally in step 5, the quality of the projection is evaluated with a suitable test image.

The configuration phase is demonstrated in figure 9. The left image shows the central tower with maximum light form the projector, while in the middle image the reference frame has been projected onto the tower. The right image shows the resulting mask for the projection.

Fig. 9 – configuration phase: (left) maximum projection light, (middle) with reference frame, (right) masking image

The real-time correction has been implemented in Unity3D. For providing independence of the location of each application, the correction images were stored on a webserver. Technically, the real-time color correction was applied to the camera as an “Image Effect” which was implemented with a shader language. Also the masking of the rendered camera image was done in real-time.

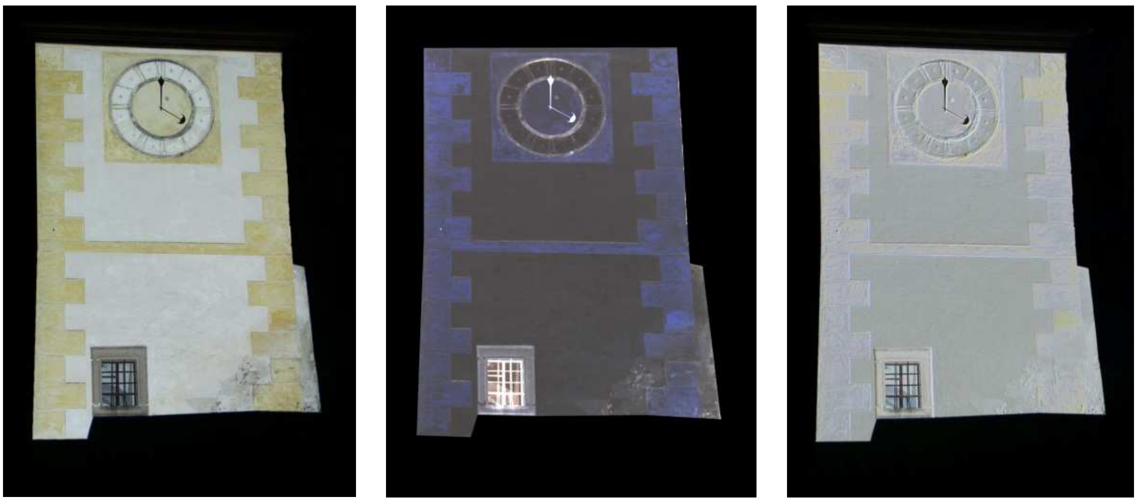

Fig. 10 – projection phase: (left) original surface texture, (middle) image for color correction, (right) combined appearance image

Results

As a first result, the projection of a test image demonstrates the quality of the approach. As can be seen in the left part of figure 11, the yellow ornaments of the tower are hardly visible. Some elements of the tower still remain fairly visible, like the hands of the clock or the window. The right part of figure 11 shows the virtual interior of the tower (inside walls, parts of the staircase) as well as a blended over section drawing from the original plans.

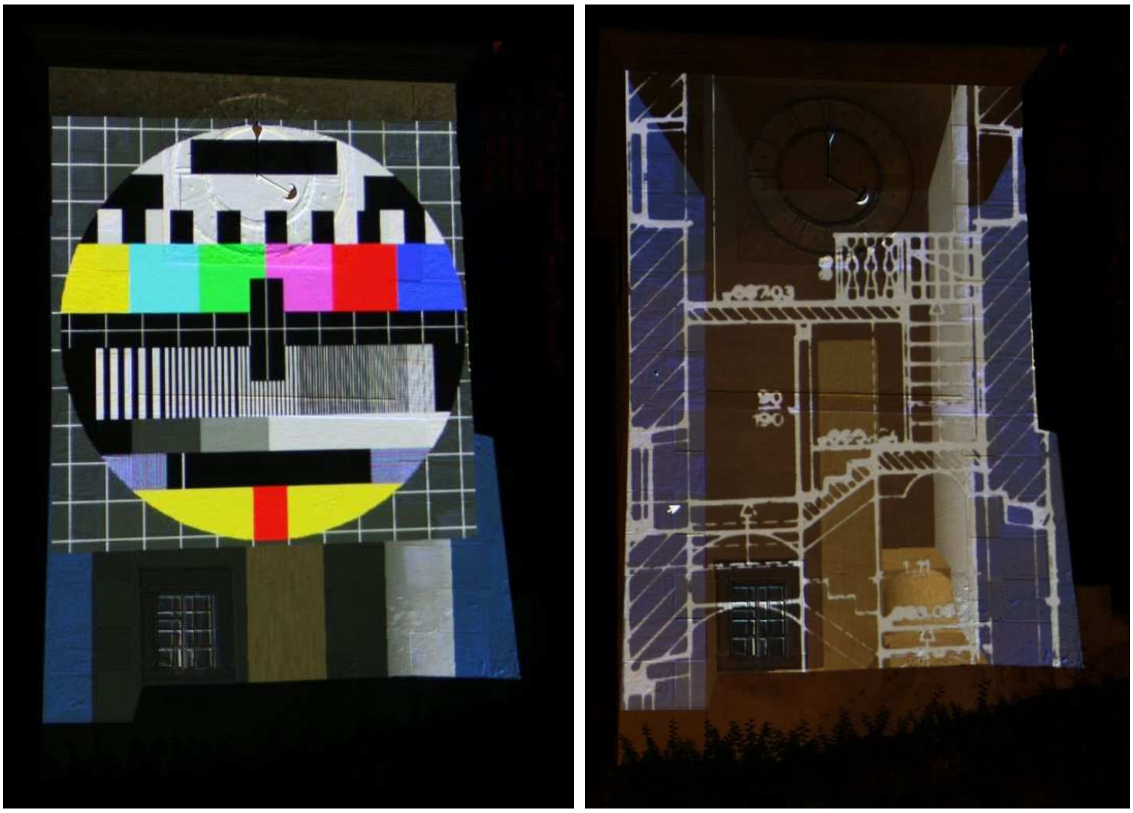

Fig. 11 – (left) projection of test image onto tower with real-time correction, (right) projection of interior and section drawing onto tower with real-time correction

For historic content, a picture of one of the ancestors of the castle owner was projected onto the tower, as can be seen in figure 12.

Discussion

With this approach we achieved a successful test at an architectural heritage site. More specifically, real-time calculation could be implemented for the necessary keystone correction and colour correction, as well as the masking.

A preferable extension of this technology would be real-time distortion correction for geometric complex surfaces. Additionally, blending several projections for larger projection sizes would be desirable, along with multiple projectors for higher light intensities.

Apart from technological improvements, more work on the richly available content would be desirable, for an educating evening event for example.

In order to take advantage of the real-time implementation, a more sophisticated user interaction could be provided, e.g. with the Kinect.

Fig. 12 – projection of ancestor onto the tower with real-time correction

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