

# Castle-Sized Interfaces: An Interactive Façade Mapping

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## ABSTRACT

Façade mapping events often assign a passive role to the audience. Due to the high pace of animations, restricted length of 12-20 minutes and audience size, integrating interactive elements is difficult. We present a case study of a façade mapping event that was designed as a Gesamtkunstwerk and total experience with several elements and phases, and solved many of these issues. Understanding the interface as an architectural piece and not as technical equipment, the interactive part was tightly integrated into the overall narrative and the interface provided a larger interaction space for multiple people.

## Author Keywords

Media Architecture; Architectural Interface; multi-user; public interface.

## INTRODUCTION

In this paper, we present our work on an interactive façade mapping presented in August 2014 in the courtyard of the castle Elisabethenburg in Meiningen. A particular challenge in this project was the number of elements involved and the collaboration with various stakeholders for the production of this ‘Gesamtkunstwerk’. This comprised a reactive entry installation in the central access archway, a façade mapping on a 120 meter long curved facade, a choreography performance by school children, and an architectural interface [4], the ‘theatre machine’ with which people could manipulate projections on the façade (figure 1).

On the technical side, a fundamental challenge was to develop and produce a robust system that combines pre-produced façade-mapping content with interactive elements. We call this ‘interactive façade mapping’. To our

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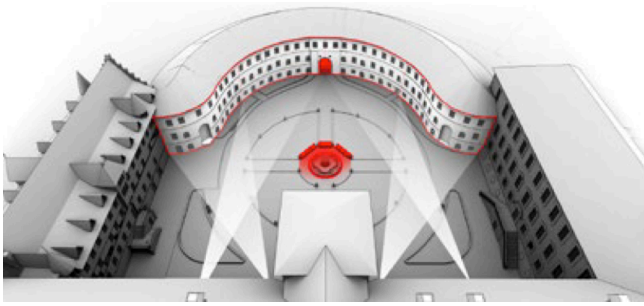
knowledge, this is the first façade projection that combines mapped animated content with an architectural multi-user physical interface for audience participation that matches the scale of the setting. Another challenge was that the performance was to relate to the history of the city, requiring use and adaptation of historic image content. Our work, as a case study illustrates the challenges and design decisions in creating a physical interface for multiple people that (1) is quick to understand and (2) can be integrated in a narrative animated façade mapping, with regard to (3) the spatial setting and (4) the story told, so that it forms a ‘total installation’ [15] or ‘Gesamtkunstwerk’. Another underlying issue was how our design process could accommodate these requirements. In this paper, we propose the term ‘interactive façade mapping’ and describe the structure and elements of the installation. We focus on the interactive sections and their role within the overall event, the respective design rationale, technical challenges, and lessons learned.

## BACKGROUND

The term video-mapping appeared around 2008 from the VJing scene that experimented with live interactive projections. The technology can be traced back to the work of Bimber and Raskar [5] in the field of Spatially Augmented Reality. Based on principles of texture mapping, the image is warped and mapped onto the geometry of real object surfaces. Famous early examples of projection-based augmentation include the Singing Heads in Disneyland’s Haunted House (1969) (cf. [19]), with more recent uses of projection



Figure 1. The ‘theatre machine’ controls the façade mapping.



**Figure 2. Map of the castle courtyard (from [7]), with façade, projector beams, entrance (red), pathways, and fountain area.**

on buildings in Disneyland. The new technical possibilities of augmenting physical environments with integrated images were soon taken up by media artists and the entertainment industry under the term ‘projection/video mapping’ (cf. [9, 10]), quickly developing into a new art form when professional tools became available. Developments and trends are largely driven by arts/tech companies such as 1024Architecture, AntiVJ, Moment Factory, and Urban-screen. Being an event-oriented media art form, it is not well documented in the research literature. Some newer work projects on dynamic scenes, e.g. for dance performances or music videos [1, 6, 26], requiring a careful choreography to align projection and moving surfaces.

Mapping techniques can create impressive optical illusions, enhance or emphasize physical aspects, transform materiality, add virtual objects, 3D effects, complexify or simplify surfaces, or transform form/shape [9]. Nowadays the terms projection/video mapping are often used interchangeably. The term ‘façade mapping’ refers to projection mapping on a façade. Most façade mappings present audio-visual narratives with a full soundtrack for cinematic effect. A main challenge of such narrations is to not just use the façade as surface, but to develop a story that fits the architecture and location in respect to façade geometry and history/context. The temporary nature of façade mappings can be an advantage as it can provide a new interpretation of the old, with the existing façade as starting point that spectators still (mentally) see while new images are shown [3].

We propose the term ‘interactive façade mapping’ for the combination of pre-produced mapped video content with interactive elements. This translates the existing term of ‘interactive media façades’ [8] to façade mapping. A range of media façade, façade mapping and projection mapping projects [8, 11, 13, 14, 27, 29 etc.] have allowed the audience to interact with visuals, but often limited interaction to a single user, e.g. in ‘Perspective Lyrique’ where spectators could distort images with their voice [31] or with a megaphone [12]. Others employ camera-based interaction [18, 30], mobile devices [13, 14, 22, 29] and other portable objects such as umbrellas [11, 16, 20] or a control dashboard [4, 17]. In the project presented here, we rather take an architectural approach, related to what Behrens et al. [4] refer to as Media Architectural Interfaces (MAI).

## EVENT LOCATION AND STRUCTURE

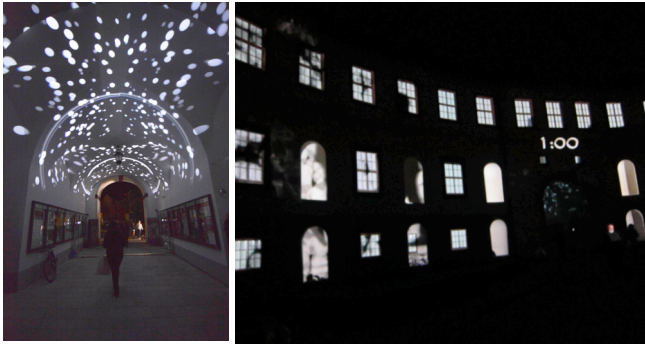
Our University was invited by the city of Meiningen to develop a façade mapping show for the 100th commemoration of Duke George II, also known as the ‘Theatre Duke’. At the end of the 19th century, the Meiningen ensemble revolutionized theatre. It introduced new ways of stage direction, ground-breaking stage designs that layered big realistic paintings to create the illusion of depth, and gave the theatre director full control over a play as ‘Gesamtkunstwerk’. The Duke was the theatre’s producer and director, was involved in stage and costume design, being an accomplished artist, and stood behind many of its innovations.

One of the core requirements for the event was that citizens of Meiningen could identify with it, learn about the theatre, and to relate to the city’s history. It was decided to advertise the show with a fictional but curiosity-stimulating story that piggybacks on historic facts. The story was that in the city archives, sketches by the Duke of a previously unknown **theatre machine** had been found. This machine was recreated and can be used by the public. The façade mapping tells George II’s story and symbolically illustrates the 12 Meiningen principles of classical theatre. The mapping reinterprets these, some in abstract form, others playful.

The project was developed by an interdisciplinary team and involved various other experts and stakeholders. In autumn 2013 a team of media architecture students began to develop a storyboard and initial ideas for the event, and developed the façade mapping. An interdisciplinary team of computer science & media students and media architects developed an archway installation, the ‘theatre machine’ and supported the technical work. Other parties involved included the soundtrack composer, a choreographer, various companies for technical equipment, and city officials.

The curved façade on one side of the enclosed castle courtyard was selected as projection plane (figure 2). Its horseshoe shape allows the audience to move into the projection. The entrance to the yard is through a long archway in the façade centre. The ‘theatre machine’ was built around a fountain in the centre of the courtyard. Here, people would almost be surrounded by the projection. We wanted to encourage the audience to explore different views, experiencing the mapping either as a distant object or as a space one can move into and be immersed in. Also, different from most façade mappings that use techno rhythms and soundscapes, the soundtrack by Markus Rom used a mix of sound effects, natural sounds (bells, machine sounds), orchestral and instrumental sounds and often had the sound move along the façade, increasing the spatial impression.

The final event was structured in four parts. While visitors entered the courtyard and waited for the show to start, a reactive ceiling projection ran inside the 5x15 meter access archway. Meanwhile, on the façade in the courtyard, large shadow silhouettes could be seen walking in. Next, a 13-minute façade mapping visualized the 12 Meiningen theatre principles. The interactive sequence was preceded by a cho-



**Figure 3. The entrance archway installation and the simultaneous countdown sequence on the façade inside the courtyard.**

reography of dancing children from local schools who brought in 12 spheres that represent the principles and activated the ‘theatre machine’, which is based on a rope-and-wheel system. Then, the audience could use the machine, which has three separate sections to interact in real-time with projected images. They could move animated scenery and figures from George II’s original drawing across the façade, thereby creating their own stage play and becoming part of the history of the theatre of Meiningen. This interactive session lasted 5-10 minutes. The performance ran three times per night on two successive days.

#### **COMPONENTS AND EVENT PHASES**

A particular aspect of our work is that this is a narrative Gesamtkunstwerk, which unfolds from the point visitors enter the castle. A challenge in creating this total experience is the change of pace between its phases.

##### **Access Archway Installation and Entrance Sequence**

The archway installation (figure 3) is part of the opening sequence. It works independently, but is conceptually linked to the overall event, connecting the town-facing front of the castle and the courtyard. It is intended to attract people, create atmosphere and entertain while visitors wait for the show to begin. We developed a reactive ceiling projection (in Processing) based on simple geometric shapes in grey-scale. 2D-bubbles of varying size and opacity float on the 5-meter wide arched ceiling, which is around 5.7m high. When entering the almost 15m long archway tunnel, visitors trigger a curved line/wave that moves towards the courtyard. Struck bubbles follow this wave in a ripple effect. Amid ambient sound, each new wave emanated a water drop sound. While this system was reactive, it was to provide visitors a sense of being able to affect the visuals.

Besides of financial constraints, a practical issue for our setup was that we could not block the escape route with equipment, and not hang anything from the ceiling. Thus, camera tracking to distinguish individuals entering or leaving was not possible. Instead, we put an industrial 2D laser scanner based on time of flight measurement (a SICK PLS-101, from eBay) on the ground next to the entrance. Four short throw projectors were put up on lateral trusses at 1.7m height. To avoid additional hardware/software costs, only

two projectors were connected to the PC. Their symmetric counterpart was daisy chained, rotated and mirrored.

Once inside, visitors had to turn back to see the entry sequence of walking shadow silhouettes, indicating the flow of people entering. Over the archway, a countdown clock was projected (figure 3 right). Bubbles flow from the archway over the dark façade, slowly filling it up and revealing more and more imagery, while increasing light levels.

##### **The Façade Mapping**

Most of the façade mapping was kept in black and white, in contrast to the interactive phase. Until transitioning to the interactive scenes, which were composed of original coloured sketches by Georg II, the amount of colour very slowly increased. To unify the animation sequences of the 12 Meiningen theatre principles (animated by 5 different people), the 8 second long transitions were all created in the same style and reminded of the ‘machine’ motive. White smoke emanating from the entrance illuminated the façade, revealing the name of a principle (figure 5 left). Sections of big cogwheels were visible through windows and niches, synchronized with the sound of gears and steam engines. Occasionally, these cogwheels were also visible in other sequences. Moreover, spheres reappeared as central element throughout the animations, representing the principles.

The introduction sequence introduced drawings by Georg II, images from the city’s history and of historical characters, revealed by a moving spotlight. Then the 12 sequences for the principles followed (figures 4, 5). Some sequences utilized very abstract graphics, metaphorically illustrating the principle, for example everything moving in unison to illustrate the principle ‘lively crowds’. Others used realistic but simplified 2/3D graphics. For example, in the sequence ‘theatre is played literature’, paper pages flutter over the façade (figure 5 right). A sphere dives into and out of the façade and stirs up the pages. Then, moving light beacons shine through the windows, accompanied by a piano solo. Some scenes included humoristic elements, such as a slot machine video game for the principle ‘theatre needs funding’, showing the sphere collecting coins from the façade.

##### **Choreography of Children carrying in the Principles and Activating the Machine**

The 3-5 minute choreography sequence had three aims. The children were from local schools and it was hoped their friends and family would come to attend. It also prepared the audience for the slower pace of the interactive phase. Moreover, during the façade mapping show the machine was dimly illuminated, so people would focus on the projections. Visitors’ attention thus needed to shift, they needed to be invited and drawn to the machine. In almost dark, the children came in and danced around the fountain in costumes illuminated with glow sticks, carrying large illuminated spheres. The spheres, representing the principles and already present in the façade mapping, here became physical. One by one the principles were placed on sockets or ‘altars’ around the fountain. These lit up in different colours





**Figure 4. Façade mapping.** Top row with example sequences (photos © Candy Welz). Bottom row left: the recurring gear-wheel motive, right: interactive phase with illuminated fountain/machine and original stage design drawings on the façade.



**Figure 5. Left: Intro of animated sequence with smoke revealing the name of a principle and gear wheels visible through the windows. Middle + right: Two detail views of animations (façade breaking up and book pages fluttering from the façade).**

once a principle was placed (activated by hand in Wizard-of-Oz fashion) (figure 6). At this point some of the audience had moved towards the fountain to watch up-close. Once all principles were placed, the entire machine lit up. The children then began to drag the ropes, acting as comperes [2] and invited audience members to take over.

The hollow sphere structures are built from laser-cut MDF and illuminated in different colours, to be visible from afar. The sockets (figure 6 right) are built in a similar style as the interactive machine, from wooden profiles, and were built to be both sturdy and transportable in collapsed form.

### Design Interactive Machine

The main concept of the interactive machine is that visitors can move theatre scenography elements along the façade using a rope interface. The idea was inspired by pulleys and ropes used to move theatre curtains and shift heavy stage elements. Similar to the layering of theatre coulisses, three layers of animated content could be moved independently along the façade from separate machine sections. The layers show original drawings by George II and allow visitors to explore and experiment with them (figure 7, right). The background layer comprises scenery (houses, mountains) stitched into a continuous image. A middle layer consists of larger scale objects and figures (trees, actors in costume), that do small gestures when the layer moves. The top layer represents the four seasons via continuously falling leaves, flowers, and snow, adding dynamics to the scene. Pulling a rope moves its associated layer. Similar to the start sequence, the façade windows and niches act as peepholes onto a background layer with huge gears turning. Gear wheels are also depicted on the very far sides of the façade. The soundtrack consists of looping premade audio which

alternates between different moods, and real-time machine gear sounds whenever the ropes move.

Design aims included to enable a larger group of people to be active, to fit the architectural scale of the setting, and for its style to align with the story of the historic sketches. Three rope interfaces were distributed radially around the fountain (figures 2, 7, 8), with the existing pathways naturally segmenting them. A wooden base frame pulled the rope apart, with bicycle wheels at both ends acting as pulleys. The frame was embedded within a curved decorative shell which not only increased the perceived size of the machine and housed standard AV lighting, but also increased stability (figure 8). This shell used the shape of waves, made from an alternating pattern of wooden profiles, and was a separate structure, enabling us to continue adapting the technical mechanism. Incremental Siemens 6FX2001 series rotary encoders were used to read directional information from the wheels pulled by the rope. In addition, add-on detachable rain covers safeguarded the technical mechanism while still allowing access to the rope.



**Figure 6. Choreography and sockets with principles.**





**Figure 7.** Left: Daytime photo of ‘theatre machine’; Middle (© Candy Welz): Machine in use with fountain and spheres visible; Right: Machine and manipulated layers of historical images (visible: 2 figures in costume, backgrounds of mountain and houses).



**Figure 8.** The structure of the machine with decorative shell and base frame, seen in daylight and illuminated during the event.

To scale the interaction up, the machines were as big as possible. A longer rope section enables more people to interact (indeed we observed bystanders helping to pull), and provides space for observers. This eases the transition from bystander/observer to performer [21]. Having three identical but independent machines simplified interaction, e.g. negotiating which direction to pull. Moreover, after watching or using one machine, people knew what to do with the others. In terms of effects, the three independently moving layers created sufficient visual complexity to engage the audience with the projection, while avoiding competition over ‘screen space’ and territory on the façade (cf. [28]).

From early on in the design process, a priority was to tightly connect the machine with the entire event. While we initially wanted to integrate the fountain into the machine, an on-site visit revealed that the fountain could block the machine users’ view. Moreover, the machine was not allowed to touch the fountain, which is a listed monument. The site-visit also inspired us to subdivide the machine into three sections, fitting on the existing pathways and spaces around the fountain. Several alternative designs for the machine were rejected: a long, vertical rope that changes imagery when pulled (problem: would visitors agree in which direction to pull?); a control desk (too complicated for the short interaction timeframe); pressure-sensitive floor plates (not clear enough to understand quickly).

Our observation from the event is that the rope interface was effective. Once the audience realized they were allowed to use the machine, the rope and wheel provided clear physical affordances [13]. Moreover, the mechanism inside was visible so people could see the wheel mechanism turning and the rope moving, strengthening the machine

metaphor and being easy to understand. In retrospect, this turned out to be potentially advantageous over a technologically more sophisticated pulley-system solution, which we had not been able to afford. In addition, the rough aesthetics of the machine, built entirely from recycled materials such as bicycle wheels and wooden beams, suited the historic (and steampunk-style) theme of the event (figure 7 and 8).

#### **DISCUSSION: CHALLENGES AND LESSONS LEARNED**

Our project encountered many of the challenges discussed by Dalsgaard & Halskov [8], in particular, ‘integration into physical structures and surroundings’ and a high need for ‘robustness’ and stability in open-air settings. Different to most façade mappings, our project took an orchestrated Gesamtkunstwerk approach, comprising several distinct elements and phases, and included architectural aspects. This increased the number and complexity of decisions aimed at retaining unity of the event, such as the use of recurring visuals and sound (gear wheels, spheres), both in digital projected form and physical. Core aims of the design were that the interface and the interaction should become part of the story and narration of the Gesamtkunstwerk. For this reason, elements of the physical machine are represented in the story and vice versa. We also had to consider how to shift people’s attention from one area of the setting to another for different phases, or how to prepare for the change of pace from the rather fast projection mapping to the interactive phase. This was accomplished by the children’s choreography that decelerated and changed the atmosphere.

To start with, the style of the ‘theatre machine’ worked well. Not only did it fit the storyline, but also attracted curiosity, while enabling users to see the mechanism. The machine attracted users across age groups; we observed sever-

al groups of senior citizens interacting, chatting and laughing. We further believe that the curved façade contributed to the immersive feel of the show. Different from other façade-mapping events, where the public tend to stand as far away as possible from the projection, our audience scattered all over the courtyard, many right in the middle. From our own experience, different standpoints provided a different experience, from a more detached but complete view, to being immersed in the projection. Thus, intentional ‘positioning’ of the audience can be part of the situation design.

Working with and in a historic site often required creativity in search of viable solutions. The placement of projectors and sensors was constrained, not just for health&safety, but also because nothing could be attached to listed structures. Furthermore, façade mapping requires a precise 3D model. Yet existing CAD drawings of the castle turned out to be inaccurate. With historical buildings, distances will not be uniform, and every window can have different measurements. We thus had to re-measure the 120-meter façade and all its elements. On the content side, video mapping with historical images required a lot of material editing, e.g. merging different background images into a seamless canvas, with careful selection and stitching, colour correction, and creation of a continuous sky replacing the original ones.

As mapping software we initially utilized MxWendler, which is optimized for pre-rendered content to reduce GPU load. It converts all files into a proprietary format of image sequences, buffering them in blocks of several seconds. This did not allow to ‘scratch’ video layers back- and forward as needed for the interactive phase. We switched to Resolume Arena 4. Usually multi-projector HD façade mappings split up rendering to multiple PCs synchronized via OSC. However, experts warned against this approach, as this could create latency and synchronization issues for the interactive phase. Thus, we used one media server for the 6400 pixel wide video. Unfortunately, streaming 17 minutes of pre-rendered video plus the 30000 pixel wide, 3-layered interactive sequence now exceeded its graphic memory, resulting in a crash. As a work-around, we restarted the software during the children’s choreography to free up memory. We would advise to either stream interactive media from several servers, or to monitor GPU performance during testing. Rendering and processor load of the video-mapping machine are always in a trade-off with resolution and frame rate, which can best be addressed by selecting optimized hardware and codec. Other challenges included that during development and testing, we only had access to trial versions, and thus could test the final software settings only on the last days during rehearsals.

Another lesson learned is that it proved effective to utilize existing reliable solutions that were adapted for our needs, from sensor technology to construction techniques, instead of developing novel solutions. The industrial sensors used are engineered for a rough environment and guarantee reliable operation in a large range of environmental settings.

Similarly, for the machine, common construction techniques for modern buildings were utilized that separate building structure from the façade. In our case, the interface was split into a functional base frame (including a rain protection add-on) and a decorative shell.

Throughout the project, prototyping, in particular in 1:1 scale and testing, as well as in-situ work were central for success. Several 1:1 scale prototypes of the base frame of the theatre machine with the technical mechanisms were built and tested repeatedly in the lab. This not only allowed to test and enact the interaction, but also resulted in several iterations to increase the mechanism’s robustness and the frame’s structural stability. In various iterations, the machine design was improved to be sturdy, carrying the rope weight and keeping rope tension. Separating base frame and detachable decorative shell allowed us to delay decisions about interface size, as the rope could be extended easily. We also experimented with suitable sizes for the principles so these were comfortable to handle in the choreography.

The prototype for the theatre machine was tested during an early on-site visit, connected with consumer projectors to get a sense of how it would feel to move content along the façade and to experiment with different setups in the social situation of watching the façade. Testing mapped video on site (even just on a façade section) was also helpful to get a sense of the perceived speed that moving objects on the façade would have – it is higher than it appears when projected on a scale model. During early conceptual development we already used site visits to enact on site what it would feel like to perform certain actions and to develop an embodied understanding of the dimensions of the site [23] as well as to test visibilities and viewpoints. We realized that given the spatial setup, collaborative interactions would work better for the interactive phase than a competitive game. This guided placement of the interfaces in a half-circle around the fountain. In retrospect, having several sections manipulate distinct layers provides a solution to the territoriality issues Wiethoff et al. [28] note for façade projection interactions that arise when people are not aware of each other’s actions and end up ‘overwriting’ each other.

In conclusion, our architectural interface provided a coherent way for multiple users across age groups to interact with the Gesamtkunstwerk. We expect more architectural user interfaces to be explored in the future in media architecture.

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