Designing an Interactive Tactile Relief of the Meissen Table Fountain

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Abstract. In this paper we highlight the practical experience gained during the first design iteration of a tactile relief for the Meissen table fountain exhibited at the Victoria & Albert Museum, London. Based on a 3D scan, we designed a 2.5D relief that is usable for our gesture-based interactive audio guide. We present a mixed-perspective view projection technique that combines the advantages of a top-down view and a frontal view, and developed a detail-preserving depth-compression technique to flatten less important parts. Finally, we present the results of a preliminary evaluation with 14 members of our participative research group, and give an outlook for improvements to be targeted in our ongoing research.

Keywords: Tactile Relief, Blind People, Visually Impaired People, Design for All, Accessibility, Museum.

1 Introduction

Tactile models are an important aid for blind and visually impaired (BVI) people to help perceive images and objects that are otherwise difficult for them to comprehend. However, tactile models need to be carefully designed in order to convey the important information, without being too complicated to read.

In this work, we report on the practical experience of designing a tactile relief of the Meissen table fountain "The Triumph of Amphitrite", exhibited at the Victoria and Albert (V&A) Museum in London. This design is especially challenging, given a number of restrictions. Although the original is three-dimensional, our goal was to create a 2.5D relief version, which is suitable for our developed gesture-controlled tactile audio-guide [9] that detects certain hand gestures during tactile exploration using a depth camera mounted above the relief, and offers location specific audio descriptions. For this work, the implementation was extended, and is now based on the HP Sprout 3D workstation, an all-in-one computer with a built-in depth sensor, touch-screen, desk lamp and projector, which makes it suitable for the use in museums. Our new software version includes registered projections onto the tactile relief, as an additional information layer for seeing people, which we currently use to highlight the interaction regions. However, this setup limits the maximum usable relief size.

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Therefore, the challenge was to present all relevant information needed to be conveyed in a single 2.5D tactile relief, with a limited size of maximally 30 × 40 cm. In addition, reliefs have a limited depth. We typically design tactile reliefs within 25 mm of dynamic depth for the content, plus a fixed base of 10 mm. This ensures that the relief can be machined easily with a three-axis CNC milling machine, and that in the new setup projections may work smoothly. As we currently can't produce undercuts, too high reliefs also tend to become less aesthetic, especially at large depth discontinuities, where a steep vertical wall is created.

For the first relief prototype of this scene we developed a special projection technique to simultaneously show the top-down layout of the fountain, while retaining the frontal view of the different statues. In this way, it is possible to convey the depth ordering and the arch-structure the different pieces describe, and give a plastic rendering of all parts from their most interesting side to show all details. Additionally, we used a custom-built detail-preserving compression technique to flattened less important parts, in order to save the limited depth budget for the more important objects.

The whole process is tightly integrated with the participatory research group of the project ARCHES[1] which consists of a varying number (around 10-40) of people "with differences and difficulties associated with perception, memory, cognition and communication," who bi-weekly meet in the museum and discuss the advances of the tools developed as well as perform their own projects and research. Accordingly, this work targets a wider range of people (not only BVI people) to create a more universally rich museum experience. Preliminary results already indicate that the integration of the tactile sense with tactile reliefs is also helpful for some people with cognitive impairments.

We describe all the steps from the artwork selection process (which included the participatory research group), data acquisition, relief design and results of a first evaluation of the tactile relief by the participatory research group.

2 Related Work

Tactile reliefs of art works is still a relatively new field of research. With the rising popularity of 3D printing, researchers started to adapt it to create 3D replicas and teaching materials for BVI people (e.g. [13, 14, 16]), to create tactile street maps (e.g. [6]), or children books (e.g. [11, 12]). For paintings, raised line drawings have been extensively used and detailed guidelines developed (e.g. [1, 2]). Although Ericsson [3] argued that "high reliefs are difficult to interpret", reliefs have successfully been used to convey paintings, as 3D shapes and surfaces can be rendered in more detail than what is possible with the limited expressiveness of raised line drawings. Formal research was conducted, e.g., at the Instituto Cavazza [5] with hand-made relief interpretations of paintings. Since then, computer scientists started research into reproduction of existing reliefs [7] and to simplify the creation and design process itself (e.g. [4, 10]). Apart from paintings, also three-dimensional objects can be presented in relief form, e.g., demonstrated on replicas of knives [8] that were more robustly presented in high relief

[1] See project website at http://www.arches-project.eu/.

but were essentially 1:1 copies of the upper surface. In this work, we practically explore the design process necessary to convert complex 3D scenes into tactile reliefs.

Fig. 1. From left to right: a) The table fountain as displayed in the museum. b) Realistic rendering of the final tactile relief design. c) Produced tactile relief CNC milled from DuPont Corian® used in our interactive audio-guide with projected colors indicating interactive regions.

3 Design Process

3.1 Participatory Process of Choosing Artwork

During the first phase of our project, a participatory research group in London was introduced with a list of objects, considered by the V&A as a warm up activity. The selection was based on the access within the physical space, but also made according to the popularity and significance of the objects. One of it was the 'Meissen Fountain': A Meissen table fountain named "The Triumph of Amphitrite", created in 1745-47, approximately 3 meters wide, 50 cm at the highest point, which was actually used with water. The participants then explored a number of different galleries with a wide range of objects over the course of two sessions. Early in the project, participants were introduced to the technology partner's company profiles. We explained the products our project was aiming to deliver and purpose of the diverse visits. With that information and based on their interactions with the objects participants voted anonymously for one object that they wanted to have reproduced more than any other. The top five answers formed a shortlist, which included the fountain, three other 3D objects (a bed, a harp, a statue "Nature") and one painting. According to the project's plan only 2D objects – specifically paintings – should be processed. After visiting the V&A we realized, that this museum is to a good part dedicated to decorative objects and therefore, although our workflow is targeted at paintings, we decided to make an exception and use a 3D object. On that account, we had to gather data via a 3D scan of the object. The selection of the object was therefore largely dependent on whether or not we could actually scan the object as it is exhibited in the museum. Preliminary tests with a photogrammetric scanning method indicated, that the statue "Nature" and the fountain would be ideal candidates. The final decision was made when we found out that a scan of the fountain was already available. Fortunately, the fountain was also the most voted object in the user survey. The main attraction towards the object was the different elements it had and the rich history of it.

3.2 3D Data Acquisition

As mentioned before, detailed laser scans of the fountain were already available. This was a by-product of the restoration efforts[2], where missing pieces were re-created from laser-scans of remaining pieces found at the Meissen factory. However, only scans of around 35 individual porcelain parts were made, and had to be correctly assembled. We could get an approximate arrangement – completed by copied and mirrored parts – that was made for a short rendered video clip. In order to create it as accurately as possible to the setup in the exhibition, we created an additional photogrammetric scan created from around 900 photos (including 260 in HDR) shot in the museum, and reconstructed using the photogrammetry software Reality Capture[3]. All individual high-quality scans were then exactly scaled and aligned to the respective parts in this scan. Missing pieces were replaced and scan artifacts corrected. For instance, for the front wall only one straight part was scanned, but the actual setup consists of 15 irregularly broken pieces which we manually modeled according to the photogrammetric scan.

3.3 Design Considerations and Viewport Selection

For this particular object we identified three main aspects which should be conveyed:

1. The general setup, i.e. the arrangement of the individual porcelain parts, and the overall shape. For instance, there are 5 main groups of figures arranged in three depths layers: a) the main group around the smaller basins centered in the back, b) two river gods in front of the main group slightly shifted to each side, and c) two vases marking the front and outer-most edge. These are connected by curved stone walls that form a characteristic arch structure, and a contoured lower wall in the front. These define the border of the water pond.
2. The arrangement of the individual figures in the figure groups, especially in the main group, which consists of three platforms, five human and two horse-like creatures and a number of other details.
3. The details of the different figures which were crafted very carefully.

Unfortunately, there is no single view that conveys all three aspects at once. The general setup (1) is best observed in a top-down view (see Fig. 2a), where the different figure groups can be differentiated, and the arch structure is best observed. However, this view is not suitable to differentiate the individual figures (2), nor their details (3). These details are best explored from a frontal view or from slightly above (see Figs. 1a and 2b), but the depth of the scene would be largely lost, as a relief has limited depth. We wanted to use a large portion of the available depth-budget to convey the 3D shape of the figures, thus as little as possible should be used for the overall depth. And since we wanted to have everything in a single relief for our interactive setup, we decided to create a mixed perspective view to convey all three aspects simultaneously.

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2 A video showing the restoration efforts is available at https://youtu.be/9AKtrtqpCag.
3 Reality Capture's website is available at https://www.capturingreality.com/.

For this, a skew transform was applied in the yz-plane, so that the distance from the front (y-coordinate) is added to the object height (z-coordinate). The effect is that more distant parts are transformed up in the relief when viewed from the front (see Figs. 3a and b). In this way, the arrangement and the arch structure is apparent in the bottom lines of the objects, while everything is still viewed from the front to convey all details (see Fig. 3d). In addition, the figure groups were tilted individually to view them from their optimal position. For instance, the center group was tilted 30° to the front to allow a better view into the basins and to separate the figures further to distinguish them more easily. In addition, all figure groups were enlarged with respect to the less important walls, in order to convey more detail, without destroying the overall appearance.

Finally, there is a contextually important relief scene on each river god's base, which is, however, too small to be perceivable. To enhance tactile exploration, we added enlarged versions of these reliefs in the free space on the top of our composition.

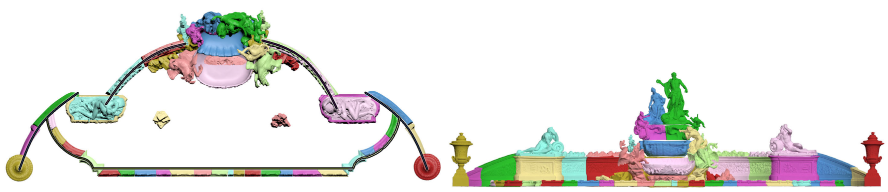

Fig. 2. Original scan data. a) Top view, with wall approximations in black. b) Front view.

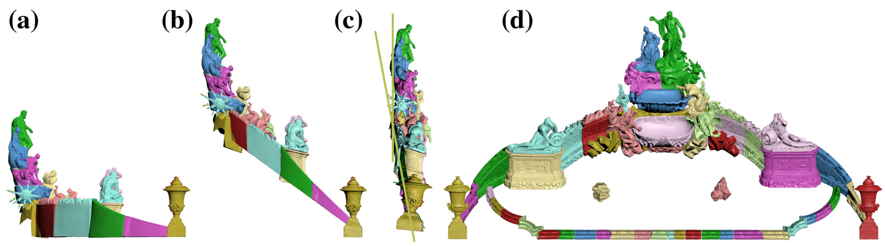

Fig. 3. Stages of relief design. From left to right: a) Original scan, left view. b) Skewed version, left view. c) Final compressed form, left view. d) Final form, used in relief, front view.

3.4 Flattening and Production

As mentioned before, a 2.5D bas-relief only has a limited depth budget. Therefore, it was necessary to compress the depth where possible, in order to maximize the available depth for the individual figures to make them as plastic as possible. Although there is a body of research to automate this process (e.g., [15]), we opted for a manual procedure in order to have more control over the process and to optimize the result.

The basic idea was to largely eliminate the depth of the connecting walls, as this information is already present in the skewed version (see Fig. 3c). All figure groups were arranged as far back as possible without destroying the local depth order. In addition, deep parts of individual figures were compressed as well, e.g., the horses' necks.

However, a simple scaling technique did not work for the curved walls. Flattening these would also flatten their surface textures. The solution was to construct a smooth shape that approximates the shape of the walls (see black lines in Fig. 2a), render this approximation into a depth map, and subtracting it from the original object's depth using a displacement shader, making it globally flat but preserving the details.

The result was a reduction of scene depth to around 20%, without scaling the depth of the figures. In order to minimize depth discontinuity to the background a background plane was added in the lower portion. A final depth reduction was possible in this particular case, as the scene was gradually coming forward at lower parts. Instead of carving it from a thicker block, we rotated the scene by 5° forward and carved the result out of a thinner block, with the idea to present it later angled the same 5° backward.

The final relief was milled out of a solid block of DuPont Corian®, Glacier White, with a final size of 30 × 40 cm using a three-axis milling machine and a spherical milling tool with 3 mm diameter. A last minute change forced us to scale the relief to a total depth of only 12.5 mm dynamic content, half of the designed height of 25 mm, as the manufacturer was not able to produce it with this particular design.

4 Evaluation

Until now, two test sessions were conducted with a total of 14 users with a diverse range of access, four of them visually impaired. Apart from three participants all had experienced the fountain in the museum environment. The users were presented with the relief, without the projections or interactive audio-guide, and without the planned 5° tilt, but with a large printed photo of the fountain. Prior and during the evaluation participants had one to one support, explaining the purpose of the relief, and rephrasing the questionnaire if necessary.

General questions were answered very positively. People liked exploring the relief (average of 1.4 on a 1-5 Likert scale), found it easy to explore (avg. 1.3), and all but three found to have a generally good impression of the fountain, some mentioning "it is nice to touch" and "I quite like it". However, when asking for details, some design problems came apparent. Four people wanted the relief bigger, one only the top river god reliefs. Many had troubles identifying all figures in the central group, found them not well separated (avg. 3.6) with the wish to make it simpler and bigger. It was a bit better to find the water basins (avg. 2.2, three people voted 5), and to notice the curved wall (avg. 2.0, four voting 3 or worse). Questions regarding the depth order of the main objects caused a lot of problems, with several people not being sure which are in the front and which in the back, some thinking they are at the same level or even the central group in the front.

5 Conclusion and Future Work

In our work, we used a participatory process that includes people with impairments in the process of making museums and other exhibition spaces more accessible to them. We showed in detail the design process necessary for conversion of a full 3d object into a tactile relief, which may aid as a starting point for similar projects. We developed a mixed perspective method to convey the ground layout and the frontal view simultaneously, and a method for flattening curved parts in order to save the relief depth budget for more important parts.

The preliminary results of the evaluation of the first prototype let us come to the conclusion that the relief on its own is of too complex nature for a wide range of people to enjoy. Though participants liked the texture and material when it came to analyze the conversion of the object from 3D to 2.5D it became noticeable that the size and depth of the figures confused the participant's concept of distance.

We believe that the mixed perspective is a good way to convey all the information, although current evaluation results indicate the opposite. We will conduct further tests, with the planned 5° tilt in place, and combined with projections and the interactive audio-guide, verbally describing the layout and giving detailed texts when touching individual parts. Based on these results, either an improved version of the relief will be produced, or an additional detail will be created as a second relief or a 3d model. Possibly also a separate simplified plan of the fountain may help.

Apart from that, we plan to improve the tactile audio-guide to include multimedia information on the HP Sprout's touch screen and on the tactile relief, and to explore further interaction methods in order to create a single platform that caters the needs of a wide variety of visitors. Possibilities for projections include: original color, high-contrast modes, or highlighting areas that the audio is currently referring to.

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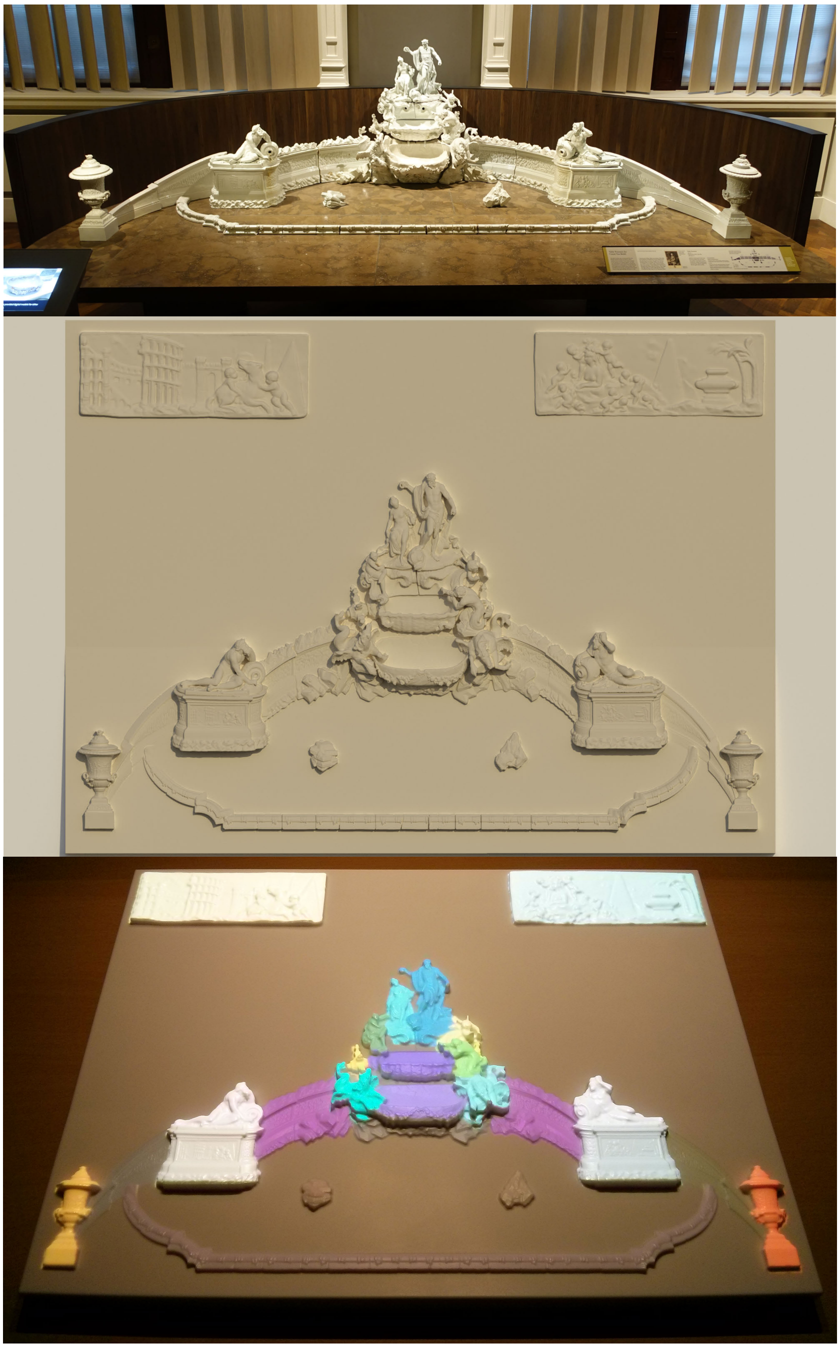
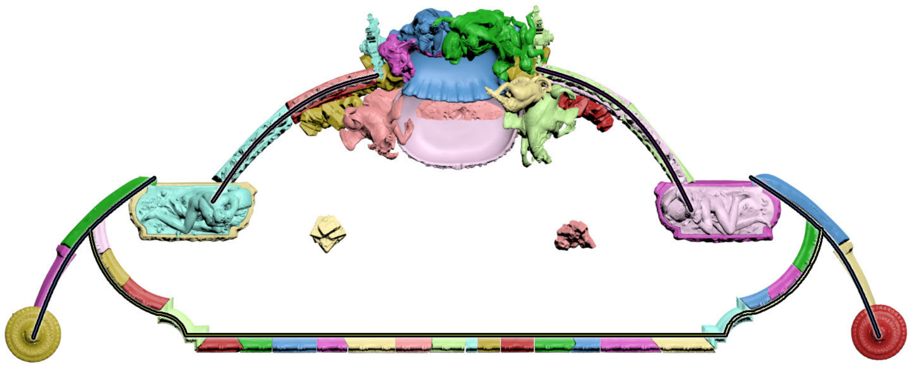
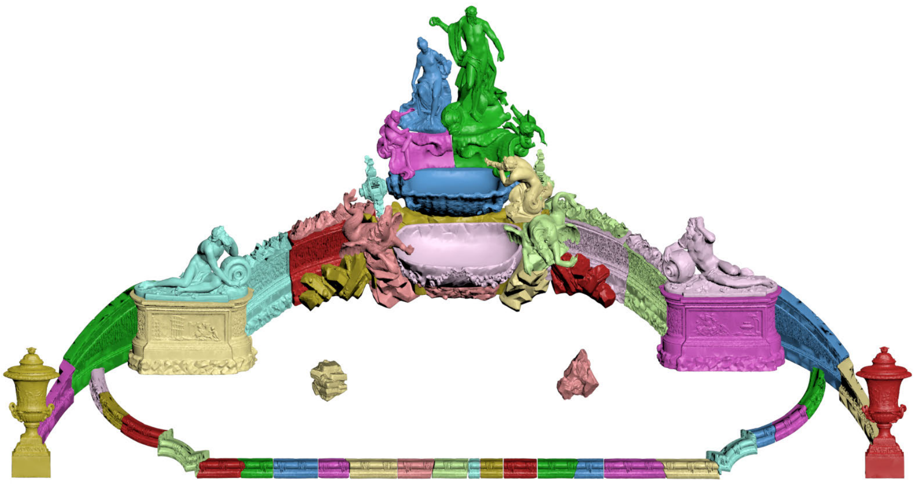
Larger figures (than in final publication)

Figure 1



Figures 2 a), 2 b) and 3 d)





Figures 3 a) – c)