Spaghetti, Sink and Sarcophagus: Design Explorations of Tactile Artworks for Visually Impaired People

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NordiCHI `16, October 23 - 27, 2016, Gothenburg, Sweden

ACM 978-1-4503-4763-1/16/10…$15.00
DOI: http://dx.doi.org/10.1145/2971485.2996471

Abstract
Technology holds significant value for supporting visually impaired people in experiencing cultural heritage. Creating tactile adaptions of artifacts or paintings is a challenging task that comprises the need for a careful surface design, a good choice of material and interaction design sensible to the needs and abilities of the target group. This work presents three design explorations aiming at better understanding material qualities and effective interaction modalities. Along with a description of the design explorations, we present feedback from visually impaired museum visitors collected in field trials.

Author Keywords
Tactile reliefs; visually impaired people; finger tracking; haptic devices; design case.

ACM Classification Keywords
H.5.2 [Information interfaces and presentation (e.g., HCI)]: User Interfaces

Introduction
Museums play a fundamental role in conveying cultural heritage to visitors. However, for blind or visually impaired people (VIPs) the experience is limited since

Figure 1. Reproduction of original painting (above, © KHM-Museumsverband) and 2.5D tactile relief model created by our design process [11] (below, © Reichinger) for Albrecht Dürer, "Virgin Mary with Child", dated 1512. The tactile model is created in high-relief with up to 2.5cm height variation. This technique allows to easily differentiate between the different objects, conveys depicted depth and allows to feel painted texture converted into subtle height variations.

most art forms heavily rely on the ability to see. Our project focuses on new technologies making museum objects accessible for VIPs. The main goal of the project is to improve the perceivability, usability and user experience of tactile adaptions for VIPs. Further, more cost-effective creation and manufacturing methods for museum staff and curators are important as well.

While 3D artworks are either directly accessible or rather straight-forward to translate into tactile models, 2D material requires further processing, typically by rendering graphical content into 2.5D relief or 3D tactile models [3] (also see Figure 1). Tactile objects combined with interactive modalities help VIPs to form mental representations and proved to be a good way of conveying information [2]. A broad body of research has explored materiality of tactile objects, their social function and especially tactile artwork as "experience-ables" in a museum setting [7]. While several museums already offer special guided tours or audio guides for VIPs [8], additional tactile models help to form more accurate mental images of objects [6]. In our project several approaches have been made to translate museum exhibits into tactile objects (see [9, 10, 11]).

After this introduction, we proceed with a description of the goal and design interests pursued in our project. The main chapter showcases three design explorations and relates those to user feedback gathered during two evaluations by focus groups with VIPs. We conclude with key findings and an outlook of future work.

Goal and Design Interest

The overall goal of our project is to create tactile representations of artworks with 3D digital manufacturing technology to enhance the museum experience for VIPs. This poses two design challenges: What materials and haptics are best suitable to communicate the artist's intent as well as make best use of human perceptional factors? And, how should the interaction with tactile representations of artworks function to best support VIPs? We followed a Research-Through-Design [5] approach and used prototypical design explorations to investigate the aforementioned design challenges.

Haptics and Materiality

How artworks 'feel' constitutes a key aspect when designing for VIPs. This concerns a pleasurable experience, e.g., by finding materials that feel good, and by making the most of human tactile sensing abilities. The challenge is to make it easy to understand for less experienced people, allowing detail exploration for experts (e.g., conveying visual information about an artwork with surface textures) while being faithful to the original, and following the artist's or curator's guidelines.

Interacting with Tactile Artworks

Interaction modalities with tactile representations of artworks need to be designed to support the exploration tasks at hand and how VIPs conduct them. In order to better understand such tasks, we conducted observations of VIPs exploring tactile representations, finding that they constitute a sum of different ways of interacting: Usually exploring an artwork is done hierarchically, and consists of two interaction types, albeit not strictly separated: Overview exploration, typically using both hands expansively to familiarize with the overall composition of the artwork. This overview exploration is complemented by detail exploration to investigate selected smaller points of interest, typically with the fingertips. The interaction requirements we defined in our project are described in more detail in [10].

Figure 2. X-ray photograph of the Egyptian Cat Sarcophagus with cat mummy inside.

Figure 3. Exploration of the Cat Sarcophagus during the Vienna focus group evaluation.

The importance of audio descriptions for VIPs as a supporting channel in interaction with artworks [4, 10] is well documented. With two of our prototypes, we thus integrated sensors to trigger audio-playback of related verbal descriptions, designed to be like an interactive guided tour rather than a conventional linear audio guide, and paying attention to a subtle integration into the overall museum experience. Descriptions include not only artistic and historic information, but especially focus on composition, poses, relations between the depicted objects and their color and appearance. [10]

User Involvement

In the course of the design process, VIPs as well as museum staff were continuously involved and consulted as experts and potential users. Furthermore, a formative evaluation was done with two focus groups of VIPs in Manchester, UK (12 participants, aged 51 to 84) and Vienna, Austria (13 participants, aged 11 to 72) in March 2016 (see Figures 3 and 6-9). The prototypes were displayed around the room and participants were guided to engage in each station, spending about 30 minutes on each. To assess the participants' reactions to the different technologies as well as their findings on the comparison of stations and materials, we designed a questionnaire with quantitative and qualitative questions. The quantitative questions were answerable by a 10-point Likert scale, where 1 was the lowest/worst and 10 the highest/best answer. The other questions as well as observational notes were analyzed thematically [1].

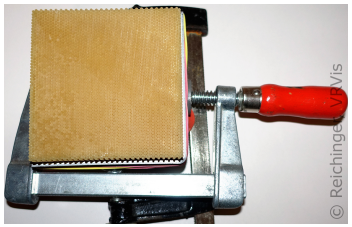
Materiality and Interaction: Three Design Explorations

We present three design explorations created in the course of our project: (1) Cat Sarcophagus, (2) Relief Printer and (3) Gesture-Based Interactive Audio Guide.

1. Cat Sarcophagus: A Digital Touch Replica

To test the interaction modality, a prototype was realized on the basis of an Egyptian Cat Sarcophagus, a 2500-year-old exhibit from Manchester Museum (see Figure 2). This 3-dimensional exhibit has been scanned and replicated using wood composite which resembles the original wooden material (see Figure 3). Following the observation results described above, a two-fold detail-level was realized in this prototype's haptic surface texture to support overview as well as detail exploration: While the right hand side of the sarcophagus is an exact replica of the object today, the symmetrical other one tries to reconstruct the original object at the date of origin and accentuates certain aspects (whiskers, tail, etc.) which can be felt in detail. To trigger contextual audio-explanations during touch exploration, touch sensors were embedded into the material.

User feedback to the Cat Sarcophagus prototype was generally positive. With the Manchester focus group, the entire group enjoyed the experience of handling the Cat Sarcophagus. Even though a replica, the similar material and exact replication gave the participants an emotional connection to the original artifact. This feedback is consistent with the one that came from the Vienna focus group. One participant stated that 'the material has its own story'. Nearly all participants enjoyed touching the object with the audio description enhancing this experience. However, some participants mentioned difficulties with the way audio was triggered during normal tactile exploration, as the system could not differentiate between touching as part of the exploration and to trigger audio, which will be targeted in the future. When being asked about potential improvements participants answered that it would be good being able to pick up the replica and to turn it around.



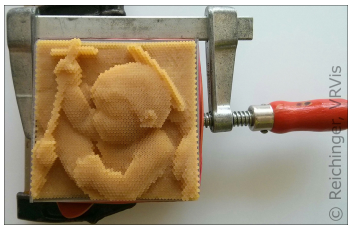


Figure 4. To 'print' an artwork, currently the relief printer is pressed on an existing relief or object, takes on the respective shape and is fixed in that position. Future prototypes will support a mechanism to shift the pins automatically and thus directly print a virtual model.

Figure 5. Close-up of the spaghetti pin matrix. Note the rough edges of the cylindrical ends.

2. Re-usable Relief Printer Medium

Inspired by Ward Fleming's well-known Pin-Art toy[1], this prototype currently consists of a large number of uncooked spaghetti as pins arranged in a two-dimensional lattice. Those spaghetti pins may be shifted parallel to each other within the lattice and when locked in place form the relief surface of the printer. Thus the printer can reproduce any form it has been pressed on in a 2.5D relief (see Figure 4). Therefore, all 2D and 3D artworks (after conversion to 2.5D) can be equally realized using this re-usable medium (details in [9]).

User feedback for this prototype was mixed. Regarding the pin size, we presented two small reliefs (9×9 cm) with varying pin diameters: 1.75 mm (37.7 pins/cm^2) and 1.15 mm (87.3 pins/cm^2), as well as a larger relief (20×20 cm) with 1.15 mm pins. Answers about haptic quality widely varied from 'pleasant' to 'sandpaper'. Participants stated that due to the rough edges of the noodle pins (see Figure 5) 'fingers do not easily glide' which was perceived as negative, sometimes described as distracting during detailed touch exploration. Rounding the pins could alleviate this. In general, users preferred the higher resolution with the thinner pins, but found all reliefs acceptable.

In summary, these three versions of the re-usable relief printer were tested. Although still being in a prototypical form, it already enables quick on-demand copies of existing reliefs and 3D objects, supporting museum staff and visitors in various usage scenarios. With the planned printing mechanics (Fig. 4), rapid realization of touch reliefs directly from digital models will be possible, requiring little display space and no storage space.

[1] http://www.pinscreens.net and http://pinscreens.blogspot.com

3. The Kiss: A Gesture-Based Interactive Audio Guide

This prototype constitutes the result of an effort to both *improve the haptics*, especially to make it more pleasant, and *externalize the touch sensors to* support different gestures. This makes authoring more flexible, reduces production efforts, and even allows interactivity on objects in which sensors may not be embedded. It was done on basis of Gustav Klimt's painting 'The Kiss'.

MATERIAL

To transform the painting into a 2.5D relief, the depicted figures and their postures were modeled based on [11], with additional character modeling in 3D editing programs. The relief design process was continuously discussed with experts from the Belvedere Gallery in Vienna and other project members. The final relief design was machined out of a solid block of DuPont Corian® in a size of 42×42 cm (see Figure 6). DuPont Corian® (color Glacier White) is a very hard and yet well machinable material, which is smooth to the touch, lets fingers glide easily over the surface and can be cleaned and disinfected easily. Due to these properties Corian® usually is used in sanitary facilities and households, for example for kitchen or bathroom sinks.

INTERACTION

We use a depth camera to track the user's finger and hand gestures and to trigger audio explanations about the painting (see Figure 7). This allows us to define interaction regions freely without modifying the object. Users can interactively explore the parts of the painting they find most interesting. During exploration of the relief VIPs can use different gestures to trigger audio descriptions on all basic parts (e.g. floor, female and male figures) and details (e.g. the figures' body parts). This prototype is described in more detail in [10].

Figure 6. Corian® relief of 'The Kiss' in the Gesture-Based Audio Guide station.
Relief: © Andreas Reichinger.

Figure 7. A participant explores the Gesture-Based Audio Guide during the Vienna evaluation. The depth camera tracks the users' gestures, which are interpreted by a custom software running in the background.

EVALUATION
Based on the feedback of the Manchester evaluation, the interaction design was refined for the Vienna focus group evaluation. For example, the first version in Manchester did not feature start and end click sounds for spoken explanations, the stop-gesture was five fingers spread instead of a fist, and playback could not be interrupted by new gestures. The modifications to the interactional design massively enhanced the usability of the audio guide.

Overall, feedback for this prototype was highly positive. When being asked whether the Gesture-Based Audio Guide gave them a better understanding of the painting, all gave a rating above 8 with an average of 9.5 (on the aforementioned Likert-scale). One person stated that 'it has to go into the museum, for eternity'. Another participant was especially touched since for the first time she got a mental picture of 'The Kiss'. Nearly all participants were highly satisfied with the underlying relief. The material (DuPont Corian®) was comfortable for most, although two people did not like it at all.

Key Findings and Next Steps

Comparison of Materials
Finding the right material for frequently used digital haptic tools is a challenge. It should be robust, scratch resistant, easy to clean, resistant to disinfectants, fit into the exhibition and be pleasant to the touch. In our evaluation we additionally and explicitly assessed the haptic qualities of three different materials in a separate station: Polyurethane (PU, see Figure 1), Corian® (like in the Gesture-Based Interactive Audio Guide) and 3D printed artifacts (printed with a nylon SLS 3D printer). The most pleasant material was Corian® (as stated by 8 of 11 participants), followed by PU (3 participants); this design exploration with relatively new materials turned out to be successful in our usage setting. Only one person preferred the 3D printed object. While Corian® was 'good/fine to touch', has a good 'hardness' and is 'nicely rounded', PU was considered to be as well 'smooth/soft' but also having 'sharp and edgy' style of design. The 3D print was mostly considered to be an unpleasant material, being 'rough' and 'less tangible'.

Comparison of Interactivity
The questionnaire was intended to find out which of the technologies the VIPs are mostly attracted to, which worked well and which left room for improvements. In general, participants preferred the Cat Sarcophagus and the Audio Guide. Both technologies offer a real object combined with location-based audio description and multimedia interaction. This multi-sensority provided great benefits to the participants: it allowed them to explore the station independently, focus on specific aspects of the art piece and experience a deep impression. The Cat Sarcophagus was especially mentioned to give a real-as-possible experience, since its material, form and size are closely following the original piece. When participants were asked which station(s) they would recommend to a friend, 10 participants voted for the Interactive Audio Guide, 7 for the Digital Touch Replica and 1 for the Relief Printer.

In summary, the Digital Touch Replica and the Interactive Audio Guide can be deployed in galleries in their current form and immediately improve the museum experience for VIPs. The Relief Printer has the potential to be a useful tool for museums or gallery staff (e.g., as a kiosk installation which offers temporary access to tactile models of the whole collection, without the need to actually fabricate and store permanent models) as

Figure 8. Impressions from the evaluation in Manchester.

Figure 9. Impressions from the evaluation in Vienna.

well as for VIPs (e.g., for home use to create tactile printouts of images while browsing the internet, or in schools to prepare tactile material for each lesson), since it can be re-used for relief adaptions of different paintings or other objects.

Conclusion and Future Work

We described three design explorations: A digital touch replica with embedded sensors, a reusable 2.5D printing element (Relief Printer) and a Gesture-Based Interactive Audio-Guide which utilizes a depth camera to capture gestures without embedded sensors.

Feedback was consistently positive for the Interactive Audio-Guide and Digital Touch Replicas. The Relief Printer currently yields a haptic that can be distracting for detail exploration, albeit it is quick and reusable and thus promising for diverse scenarios. Finding a smoother pin material, a way to rounding the ends and the development of the mentioned printing mechanics are a subject to future work. Intermediate results, especially on user acceptance of the conceived interaction modalities, are promising and exemplary to the value technology can hold for opening up the museum and gallery experience to visually impaired and blind people.

Acknowledgements

This work was performed within the framework of the project Deep Pictures, supported by the Austrian Science Fund (FWF): P24352-N23, and the Erasmus+ project AMBAVis (http://www.ambavis.eu), which has been funded with support from the European Commission. This publication reflects the views only of the authors, and the Commission cannot be held responsible for any use, which may be made of the information contained therein.

References

[1] Braun, V., and Clarke, V. Using thematic analysis in psychology. *Qualitative research in psychology* 3, 2 (2006), 77–101.

[2] Brock, A.M., Truillet, P., Oriola, B., Picard, D., and Jouffrais, C. Interactivity improves usability of geographic maps for visually impaired people. *Human–Computer Interaction* 30, 2 (2015), 156–194.

[3] Edman, P. *Tactile graphics*. American Foundation for the Blind, New York, NY, USA, 1992.

[4] Eriksson, Y. How to make tactile pictures understandable to the blind reader. *IFLA/SLB Pre-conference Seminar,* Penang (1999).

[5] Gaver, W. What Should We Expect From Research Through Design? In *Proc. CHI 2012*, ACM Press (2012), 937–946.

[6] Gilbert, J.K., Reiner, M., and Nakhleh, M. *Visualization: Theory and practice in science education*. Vol. 3. Springer Science & Business Media, 2007.

[7] Nevile, M., Haddington, P., Heinemann, T., and Rauniomaa, M. *Interacting with objects: Language, materiality, and social activity*. John Benjamins Publishing Company, 2014.

[8] International Council of Museums and Fondation de France. *Museums without barriers: a new deal for disabled people*. Psychology Press, 1991.

[9] Reichinger, A., Fuhrmann, A., Maierhofer, S., and Purgathofer, W. A Concept for Re-Usable Interactive Tactile Reliefs. In Miesenberger, K., Bühler, C., and Penaz, P. (eds), *Proc. ICCHP 2016, Part II*, LNCS 9759, Springer International Publishing (2016), 108–115.

[10] Reichinger, A., Maierhofer, S., Fuhrmann, A., and Purgathofer, W. Gesture-Based Interactive Audio Guide on Tactile Reliefs. In *Proc. ASSETS '16*, ACM Press (2016), to appear.

[11] Reichinger, A., Maierhofer, S., and Purgathofer, W. High-quality tactile paintings. *Journal on Computing and Cultural Heritage* (JOCCH) 4, 2 (2011), Article 5.