Prioritizing Aesthetic Touch: Interpreting Historical Textiles with Digital Embroidery

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ABSTRACT

A lack of accessible exhibitions for Blind and low-vision (BLV) visitors in art museums and historical sites is a barrier to equitable participation. The design and fabrication of accessible materials can be time-consuming and expensive for many institutions. We describe our work using digital embroidery machines to interpret historical textiles to provide accessible interpretations for BLV museum visitors and tactile learners. Our work focuses on designing solutions that that are informative, durable, and enjoyable to touch, while affordable to produce. Through a collaborative design process with tactile graphics experts in museums we create prototypes of historical textiles that meet these criteria. We describe our design process and offer fabrication guidelines for patterns and materials.

CCS CONCEPTS

• **Human-centered computing** → Accessibility;

KEYWORDS

Accessibility, Blindness and Low Vision, Tactile Graphics, Digital Fabrication

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1 INTRODUCTION

Tactile Graphics can efficiently communicate information to people with vision impairments and tactile learners. Technologies such as embossers and microcapsule printing produce raised text, textures, and contours on paper that otherwise would only be presented visually. We consider that these tactile graphics provide *informational* touch, and not *aesthetic* touch [6]. Aesthetic touch experiences should provide information but also connect a visitor more deeply to the source material since it conveys information about an artistic process, or the materials used in an object. To expand informative tactile experiences for museum visitors we believe it is important to go beyond informational touch and find new solutions to offer aesthetic touch experiences. This is especially important for textiles, an artifact rarely available for visitors to touch. We partnered with the Intrepid Sea, Air & Space Museum which has a collection of 40 historical embroidered naval patches. They were not "official" navy patches but were designed by the sailors and worn to show solidarity and camaraderie. Filled with symbolic imagery, these patches tell stories that are only available to visitors who can see the images or objects on display or listen to audio descriptions. In this paper we describe our iterative design process creating tactile interpretations of these patches using digital embroidery in collaboration with three tactile graphics experts (who are named as authors 3, 4 and 5), and offer fabrication guidelines to provide aesthetic touch experiences that are legible, affordable, and durable.

2 RELATED WORK

Tactile graphics, commonly made with embossers or microcapsule printing, successfully convey information where contour and line are the most important elements. Low-tech approaches are a popular alternative to interpret fine art paintings [11], [8], and reference work such as *Art Beyond Sight* [1] provides examples and guidelines for museum practitioners to create microcapsule tactile graphics of paintings. Higher tech solutions that take a multimodal approach to tactile graphics can expand their expressive capabilities. Tactile Graphics with a Voice [3] uses QR codes to connect audio tracks to the tactile graphic, enabling more information to be conveyed than was available when Braille labels were the only guiding text accompanying the graphic. Interactive Multimodal Guides [4] which use capacitive touch points positioned on 2.5D relief models of paintings can work well for more complex visual images. The paintings were transformed from simplified line descriptions of their content to a 2.5D touch object that also conveyed descriptions and context

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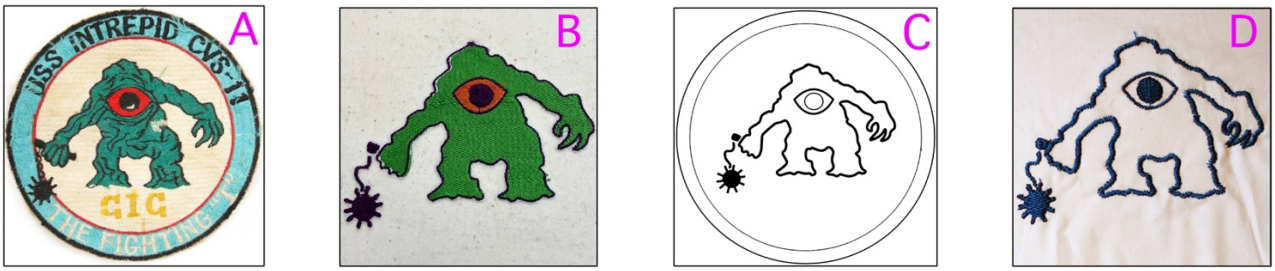

Figure 1: Our three initial prototypes of the CIC "Monster" Patch: A) Photo of original historical CIC patch, Collection of the Intrepid Museum. Gift of RD2 Fred Lugar. 2017.02.01 B) Digitally embroidered full color replica of just the monster C) Microcapsule printed outlines of design D) Embroidered outline of monster

with an audio track. Both projects provide a richer tactile experience, yet they are not feasible for many institutions, as they are expensive and require highly skilled fabrication. While past work has focused on painting, limited work exists for interpreting textiles. We think it is important to match the interpretive materials with the original materials and see an opportunity for digital embroidery machines to make this possible. We explore the potential for digital embroidery by building on work by Seehorn et al. [9], who created braille dots and tactile graphics using digital embroidery on fabric.

3 INITIAL TEXTILE INTERPRETATIONS OF HISTORIC NAVAL PATCHES

We started our work without input from tactile graphics experts due to constraints of the pandemic. We first focused on the CIC "Monster" patch, which features a green monster holding a ball-and-chain flail surrounded by text (Fig 1A) [12]. We removed the text and simplified the contours of three prototypes to explore material and tactile density: 1) an embroidered filled replica (Fig 1B) on white fabric using a standard fill stitch to match the colors of the original item; 2) a microcapsule print of the outlines and outer circles of the patch (Fig 1C); and 3) an embroidered outline on white fabric (Fig 1D) with a thick raised line of black thread. We were able to share these with tactile graphic expert (TGE) 1 who later joined our team. TGE1 has lived experience with vision loss and is an expert in museum access and touch interactions.

Overall, TGE1 preferred the embroidery (Fig 1B and D) over the microcapsule printing (Fig 1C) and liked the use of materials from the historic object to provide aesthetic touch. Though the microcapsule version was informational, it was not as pleasing to touch. They liked the use of color (Fig 1B) for visitors with higher visual acuity, but felt the fill was too flat and needed height and texture variations. They felt the dense stitch in the embroidered outline (Fig 1D) worked well to provide informative touch. We discussed the logistics of fabrication, and the tradeoffs for the high cost of microcapsule printing materials and machines versus the potentially longer fabrication time required for the dense embroidered fill, multiple colors, and potential for embroidered fabric to bunch or wear out. Given the popularity of digital embroidery machines, we agreed it is a feasible option for museums who have been slow to adopt microcapsule printing.

4 EXPLORING FABRICATION, MATERIALS, AND DESIGN FOR EMBROIDERY ON PAPER

4.1 Fabrication Tests with Embroidery on Paper

Based on feedback from the initial prototypes we wanted solutions that were affordable and easily reproducible for museum staff, while being tactilely informative and providing aesthetic touch. We chose to focus on machine embroidery on paper which would be easier for staff to work with, more durable for visitors, and less expensive than fabric. Unlike fabric, we like that paper is pre-cut and stabilizer (a stiff fabric affixed to the back of embroidery) can be easily attached. When embroidering paper, there must be enough space between needle punctures to not tear the paper. We found a spacing of 0.5mm to .75mm between needle punctures worked well depending on the type of paper and shape contours.

4.2 Paper and Thread Material Tests

We tested multiple thread and paper types for their ease of fabrication, touch durability, and tactile legibility. We used the same horizontal stitch as a fill texture to produce stitches 3-5mm long with 1-2mm distance. We tested 3 types of thread (Cotton thread, Coats & Clark brand polyester thread and Sulky brand rayon thread). Cotton thread was not effective, as it frequently jammed the machine and began to fray quite quickly, while polyester and rayon stitched well. We tested 5 types of paper (65 lbs. solid core cardstock, Marshmallow Smooth cardstock, 90 lbs. cold press watercolor paper, Clearprint 100% Cotton 16 lbs. vellum, and polypropylene Yupo paper). Although embroidery experts recommend thick paper with long fibers [2] (such as watercolor paper) the threads sunk into the heavier paper making them hard to feel. The other papers stitched well, but Vellum tore easily, both cardstocks stitched easily, and Yupo was the most durable.

4.3 Optimizing Fills, Lines and Lettering for Legible Touch

To create a set of tacitly legible designs, we studied the examples in *Art Beyond Sight* (ABS) [1] which contains pattern swatches, lines, and sample images intended for reproduction in microcapsule, and fabricated them in embroidery on paper (Figure 2A). ABS used *Dot and Solid-Rough Patterns* for fill and to represent depth. We replicated this with 1.0mm distance between horizontal rows, staggering

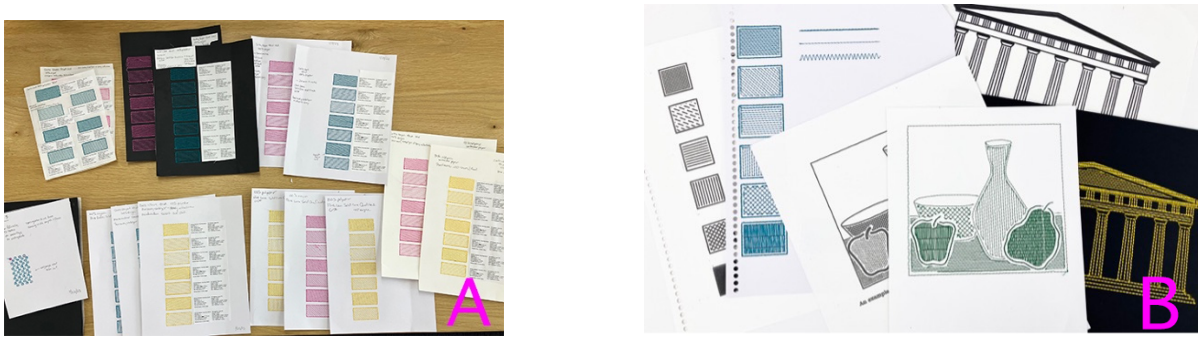

Figure 2: A) Collection of our thread and paper tests B) Embroidered and Microcapsule swatch and image tests

stitches every four lines to distribute the needle puncture holes. Seehorn [6] used a similar dot pattern on fabric to make Braille, but the stitch density of this caused the paper to perforate. ABS also used *Horizontal, Vertical and Coarse Line Fills* with a 2mm spacing between rows, which we replicated with rows of 5mm stitches that were 2mm apart. We recreated the ABS *Cross-hatched Basketweave* fill with the Eggbot/AxiDraw Inkscape extension [13] at 3.0mm hatch spacing at 45 degrees. We approximated a smooth *Solid Fill* with vertical stitches spaced 10mm and 5mm apart. We replicated all three lines in ABS with a running stitch (thin line), a repeating bean stitch (thick line), and a zig-zag stitch (detail line). Since ABS did not include suggestions for alphanumeric letters, we used Hershey Fonts [5], which are designed in a single vector line. We used a Hershey Text Inkscape Extension [10], that converts text to single path lines instead of filled outlines, and the EMS Readability Font with a 2mm or 3mm stitch distance.

4.4 Designing Microcapsule Printed and Digitally Embroidered Test Set

We created a test set of microcapsule printed and embroidered paper *swatch tests* to explore materials, and *image tests* to evaluate materials in context (Figure 2B). Our swatch tests were adapted from ABS and digitally embroidered with rayon and polyester thread on cardstock and Yupo paper. The image tests were two images from ABS: a still life, stitched on Yupo paper with polyester thread, and an architectural rendering of the Parthenon, stitched with polyester thread on cardstock. We shared these materials with TGE1 and two new tactile graphics experts (TGE2, TGE3), who also have lived experience with vision impairments and joined the team as authors and engaged in regular feedback sessions. TGE2 has expertise related to accessible interpretation in museums, and TGE3 has expertise in tactile graphics fabrication. We mailed identical materials to the experts and evaluated them in video calls.

4.5 Reflections and Feedback

Our TGEs found the test set helpful to evaluate the potential for digital embroidery and preferred these over microcapsule printing to interpret historic textiles. They had no tactile preference between the two types of paper, though all liked that Yupo paper would not easily tear, but acknowledged it was the most expensive. TGE3 preferred the rayon for its clarity, while TGE1 and TGE2 felt there was no noticeable difference. All TGEs cautioned against using too many patterns in a single tactile graphic, and TGE1 suggested limiting it to four. The Solid Rough pattern was the preferred background fill, while all found the Coarse pattern confusing. All liked the Horizontal and Vertical Patterns. TGE1 felt the Basketweave was not distinctive enough, and possibly confused with the Coarse Pattern and Solid Rough. However, TGE2 and TGE3 thought the Basketweave Pattern was useful and distinct. None of the TGEs felt that the Solid Fill patterns were legible or useful. All three found the thick and thin lines legible in the image examples and found the detail line confusing.

4.6 Applying Lessons Learned to Historical Textiles

Based on explorations and feedback, we applied our techniques to two historical patches (Fig 3). We made both with polyester thread and 65lb. cardstock with the CIC patch taking 30 minutes to produce and the Mediterranean Cruise patch [14] taking 50 minutes. We evaluated these protypes with TGE1 and TGE2 with microcapsule printed versions as comparisons. TGE1 felt that the CIC patch was legible, and that the eye of the monster was well-defined. The playing cards on the Mediterranean Cruise patch were "*enjoyable*" to touch, and using the Solid Rough fill made the shapes discernible. TGE2 commented that the Solid Rough texture *"felt like cloth."* TGE2 felt that, compared to the microcapsule versions, the embroidery provided greater detail and enjoyed the *"rhythm"* that the stitches created. Not all experts were able to read the letters and said they were *"bumpy"* reminding them of Braille (TGE1) and felt "*almost pixelated*" (TGE3). Letters that followed a curve were difficult to discern for TGE1 compared to letters on a straight horizontal path. Despite having difficulty reading the letters TGE1 felt they should be kept, as they provided context and were closer to a true representation of the original artifact. TGE1 felt that most of the main elements discernable, and lost details could be described with explanatory text or a key, as tactile graphics usually are.

5 DISCUSSION AND GUIDELINES FOR AESTHETIC TOUCH

When working with historical museum objects, it is important to discuss with curators how to balance historical accuracy with tactile legibility. We follow tactile graphic design best practices [7],

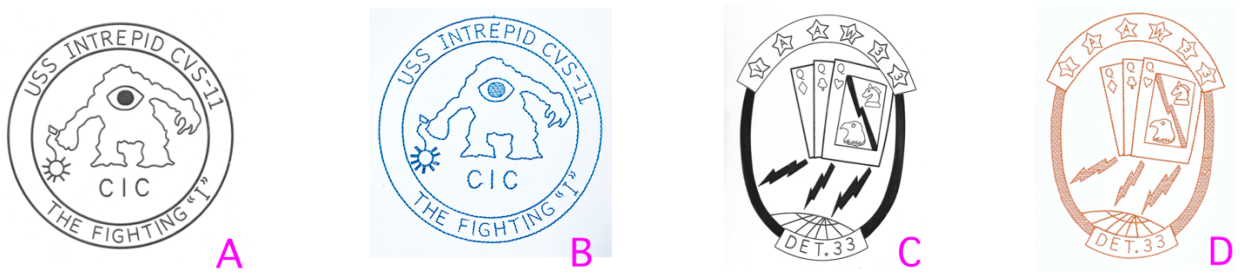

Figure 3: A) Microcapsule and B) embroidered CIC patch C) Microcapsule and D) embroidered Mediterranean Cruise patch

such as providing 0.25 inch breathing room between elements, and not overlapping design elements, and never using more than four patterns. We used Hershey Fonts to produce clear letters that stitch well with a 3mm stitch distance and reducing to 2mm for curvy or precise lettering. However, small lettering and details are difficult to make legible. We recognize the limited capacity for museum staff to produce tactile graphics and recommend Yupo paper for its durability and ability to be cleaned, but 65 lb. cardstock is a good low-cost alternative. We recommend pre-cut and self-adhesive thin stabilizer with 40 wt. rayon thread or polyester thread and running the embroidery machine at a slower speed than with fabric to minimize tearing.

6 CONCLUSION

This research has demonstrated a new technique to provide aesthetic touch to tactile graphics that interpret historic textiles. We presented results from prototyping and evaluation with tactile graphics experts. We provide recommendations to create tactile graphics using digital embroidery and encourage others to pursue both aesthetic and informational touch. As future work, we will evaluate the durability and usability of our embroidered tactile interpretations with museum visitors with a range of vision abilities and apply our heuristics to other artifacts. We are also interested in making the design and fabrication tools accessible to our tactile graphics experts so they can be involved more deeply in the design process.

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