Using Fiber Arts and Sonification to Improve Data Accessibility of Maker Spaces

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Maker spaces pose access barriers to learning the skills to 'make', barriers in using the tools to 'make' and barriers to the spaces where making happens. In this paper, we explore one facet of inaccessibility -- the assumption of vision. Images and data are central to making, and there is a need for affordable solutions that support different stages of the making process, and are suited to making workflows. We present our ongoing work with embroidered tactile graphics and sonification, and re-imagine systems of making to be inclusive.

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1 INTRODUCTION

The purpose of maker spaces is to increase access to ‘making’ among the general community [29]. By centering inclusion and accessibility in the design and management of maker spaces, we can expand the number of people making, and bring forth a diverse set of experiences and better creations. One important, but mostly overlooked group that is often excluded is people with disabilities. Although maker spaces have become a home for the Do-It-Yourself Accessibility Technology (DIY-AT) movement [7, 8, 16, 19], these movements are sometimes structured as “for” people with disabilities rather than “with” or “by” them. Recent work has begun to address this inaccessibility and exclusion through participatory design sessions and digital tools [10, 15, 27, 29]. A small body of this work has begun to explore making specifically for people who are blind or low vision (BLV) [4, 17, 28]. However, this body of work has not addressed the importance of accessible access to data in the context of making.

Images (e.g., schematics) and data (e.g., from sensors) are central to making – used for instruction manuals to diagrams to data visualizations. A key aspect of making ‘making’ accessible is to explore other ways of representing this information. There is a need for affordable solutions that support different stages of the making process – from conceptualization to prototyping. These solutions should also acknowledge the dynamic nature of data and expose nuances about the data needed to interpret and program with it. Our current work-in progress aims to address these through an exploration of embroidered tactile graphics and sonification.

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1.1 Background

Previous work has shown that making tools and processes accessible can improve participation by people with disabilities in maker spaces and promote empowerment. Some works in making maker spaces accessible include [4, 15, 19, 27, 29]. For example, JooYoung [27] introduces the SCAFFOLDING framework, a universal design conjecture and framework that takes an intersectional, inclusive approach to engage learners with diverse ranges of ability in makerspaces. The SCAFFOLD conjecture mapping presents future directions to promote inclusive and accessible maker spaces. Each work emphasizes the sense of empowerment, creativity and agency fostered through making.

On the front of nonvisual making, research has included design workshops and digital tools. The design workshops highlight key challenges such as visually labelled tools, vision centered trainings and visual diagrams. [4, 17]. These works also explore underlying stereotypes and social stigma that impact making culture and inclusion of BLV makers. For digital tools, the following work has explored making images and data accessible non visually [6, 18, 28, 30]. ShapeCAD allows BLV makers to leverage low resolution output for 2.5D shape displays to haptically explore, author, and modify 3D models. Sonification Sandbox, Data-to-Music API and SIFT [6, 18, 30] provide tools to support creation and manipulation of sonified data.

Additionally, the following works [9, 13] are great examples of BLV making. Observing the creation of interactive e-textile artworks [13] and artifacts at a communal weaving studio [9] informed design recommendations for accessible making. This highlights how people with disabilities are contributors of access (not just recipients) [3].

Previous work on tactile graphics and sonification has focused on domains such as visualizations of static data and alternative representations of art. The intersection of accessible making and data accessibility remains underexplored. Embroidery and sonification offer an under-explored low-cost solution that could integrate well with making workflows.

2 EMBROIDERED TACTILE GRAPHICS

Tactile graphics have been used to support learning of spatial and geometric concepts for a long time. Traditional techniques (such as embossing and thermoforming) create raised tactile elements on using molds or printers. However, these graphics have a prohibitively high cost of creation and require specialized knowledge to design and produce [20]. While digital designs can be disseminated, expertise is still required for production. Off-the-shelf kits or DIY materials (cardboard, glue, glitter, thread) are often used as alternatives.

Our approach, which is accessible to non-experts, familiar to many makers, affordable, and supports interaction, is to create tactile graphics using fiber arts such as embroidery and silk-screening. We present ongoing research that explores opportunities offered by fiber arts, and computational tools to support creation of optimized, multi-textured, interactive tactile graphics.

Our focus on fabric is motivated by its ready availability and variety of textures. We believe the flexibility in design and variety of texture that fiber arts offer can help produce graphics that meet user preferences. For example, fabric is compliant, which can improve comfort when reading Braille [25].

Fiber arts can provide secondary (less tangible) benefits. The skillset to create artifacts with fabric and embroidery are ubiquitous compared to the bespoke expertise and tools required to create accessible tactile graphics using state of the art approaches. Fiber arts can potentially expand *who* creates tactile graphics and *where* they are used. For example, there are many professional and hobby communities such as tailors, seamstresses, cosplay enthusiasts, and fiber artists who could participate in the tactile graphics ecosystem. Combining knowledge of embroidery from these experts with the diverse wants of tactile graphics users would allow for creation of better tactile graphics i.e. this collaboration fosters informed iteration and customization. In addition to expanding makers to include these fiber arts communities, we can reimagine who cares about and provisions access by desegregating access ecosystems from making systems.

The nature of 'making' requires representations that support iteration and rapid prototyping. To address this need for dynamic representations, we turn to e-textile literature. It is possible to embed soft electronic interfaces in textiles using conductive thread for embroidery [22]. A variety of applications such as speakers, tilt sensors have been explored [23, 31]. Interactivity has promising potential because tactile graphics are hard to learn i.e. there is some training required before people can perceive them easily. Interactive components can provide feedback to support learning. Additionally capacitive sensing can provide insight into tactile graphics users cognitive exploration of data and strategies used.

2.1 Feasibility Analysis

We have begun with a comparative analysis of different fabrication techniques' ability to convey tactile information on fabric: embroidery, silk screening and 3D printing. The latter techniques were picked for compatibility with fabric as well as prevalence in the literature.

There are several ways to create distinct textures with these techniques, for example by modifying patterns. With embroidery, the dimensions also include stitch type (for lines and fills) and stitch spacing. Additionally, couching and puff embroidery lets us introduce other materials for texture. With silkscreening, the addition of a puff additive to inks creates a raised embossed surface on a variety of fabrics. In 3D printing we can control height, infill pattern, and filament material to modify the tactile feedback of a printed graphic. Our initial exploration has focused on generating these textures.

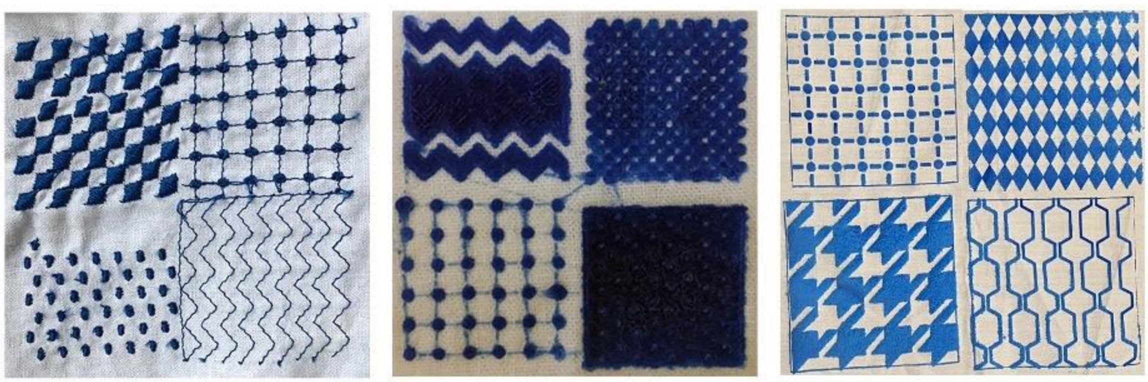

Fig. 1. Texture Swatches created using Embroidery, 3D printing and Silkscreening respectively.

Given prior production media, any graphic with more than 5 textures is too complicated to perceive [14]. But there is subjectivity in what textures are perceived as distinct, and it should be up to the user to pick those 5 textures from a range of options. Additionally, certain textures may be better suited to certain regions, eg: if a region is too small or shaped strangely, a texture that is dense and raised is preferred. Or certain textures are easier to perceive on certain textiles (eg: running stitch is too delicate for jute). These possibilities lend themselves to exploration through collaboration between fiber arts experts and tactile graphics users.

To examine this, we are generating grids of textures using each technique (Figure 1). With the same set of textures in each grid, we vary the size of the regions and the shape of the regions. In our evaluations with users, we will ask them to rate different tactile attributes of each texture (rough/smooth, hard/soft etc.) with an aim of identifying textures with high tactile contrast. Along with these within-technique metrics, we are also evaluating time to design, time to produce, robustness and interactivity across techniques. Our initial results regarding textural diversity and robustness of embroidery have been promising. We will further validate this through the user evaluations described above.

2.2 TacStich: Embroidered Tactile Graphic Design Tool

Rooted in this exploration of textures, we envision a tool that automates creation and customization of tactile graphics. Given an SVG image and user preferences for textures, we optimize assignment of different stitch and fill types for the embroidery file. An example SVG image could be of line chart from a sensor, or circuit schematics. We envision providing each user a texture swatchbook and gathering user preferences through a screen-readable web interface. The optimization accounts for informativeness, attention costs and communicability. User preferences and tactile contrast are also emphasized. Input SVGs could be data visualizations from any part of the making process such as bar charts, line graphs, pie charts or schematics for circuits, instruction manuals, 3d models. The initial swatchbook and resulting embroidery file could be iterated and modified by fiber arts experts through feedback loops with users.

For example, in the case of schematics, exploration of the resulting embroidered tactile graphic informs spatial representations further supporting debugging and modification [24]. Future iterations of this tool would embed conductive elements in embroidery files, to enable interactive audio labeling. The graphic itself could act as an interface to support modification of underlying CAD files.

3 SONIFICATION

Sonification, or the capability to convey information through sound, offers promise in many contexts such as fault detection in machines, and accessibility (to represent information in audio for BVI consumers). However, many successful tools that make information such as graphs accessible by converting them to speech and audio [2, 11, 26] do not provide information in ways that are specific to understanding how the data is generated. For example, a user could perform a gesture using an accelerometer, export data from it, and make it accessible by using one of the aforementioned tools to understand it. However, though these tools can convey this data accessibly, the post-facto availability of this accessible representation hinders the ability to perceive the noise in the data, and access other nuanced information that a BVI maker may need to understand, program based on, or debug using it. Simply put, most of the tools do not let BVI consumers get access to data as it is being generated, and do not give much flexibility in terms of what part of the data they hear and how -- essential needs to support debugging. Additionally, many resources that explain how physical computing devices such as sensors work use visual means to communicate data generated by these sensors. We argue that data sonification could support (1) data-based debugging, and (2) learning about sensors.

3.1 Feasibility Analysis

We have begun implementing a variety of options for sonification including sonifying data using speech, small audio files (such as a drop of water), and musical notes.

An interesting challenge with streaming data (typical of sensor-based programming) is deciding how to highlight interesting facets in streams, and how to handle multiple streams at one time. Connected to this is how BLV people can self-author appropriate sonifications given their data understanding goals.

Other open questions include how to interact dynamically with sonified data as it is being played, and how to visualize the information being sonified in ways that effectively support collaboration.

4 CONCLUSION

Prior work suggests that assembling an accessible making workflow requires careful balance of social factors such as being in sync with tools collaborators might use [5], technical factors such as accessibility of the tool itself [1], and nuanced informational needs to perform a particular task [21]. Understanding these informational needs and building toolkits or tools that integrate with the right set of platforms in the context of physical computing requires a multi-phased approach including both feasibility analyses and tool building.

There are also opportunities to combine these data understanding techniques. While tactile graphics offer granular explorations of spatial concepts and data, they fail to offer a preliminary overview the way vision does. Sonification, on the other hand, supports holistic perception and thus allows users to perceive larger trends and noise in data. The complementary benefits of each technique support the value of bringing them together into a multi-modal experience. For example, to support designing and building electronic projects, the Toastboard [12] reduces debugging time by visualizing the entire breadboard's state. The visualizations display connectivity information on the circuit schematics, and transient quantitative data through graphs. A multimodal tactile graphic could represent the same information accessibly by implementing embroidery for circuit schematics and sonification for graphs.

Our ongoing work on embroidery and sonification as modes of expressing data and schematics associated with physical computing has the potential to improve the state of the art in accessible, tactile graphics, include people with disabilities and fiber arts experts into the maker space ecosystem, and make tactile graphics available in contexts outside of education. We hope to help makerspaces uphold the core tenet of fostering a community-centered and diverse space where people of varying skills and common interest collaborate.

In re-imagining maker spaces as systems to be inclusive to people with disabilities, we envision involving people with disabilities as expert producers of graphics they need to consume. At the same time, we envision this process of bringing together diverse expertise, i.e. fiber arts and accessibility standards, to make an under-explored domain such as making accessible to require multiple iterations. Through community and collaboration, our hope is to go beyond just creating artifacts of access to sustainable accessibility.

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