TacTILE: A Preliminary Toolchain for Creating Accessible Graphics with 3D-Printed Overlays and Auditory Annotations

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ABSTRACT
Tactile overlays with audio annotations can increase the accessibility of touchscreens for blind users; however, preparing these overlays is complex and labor intensive. We introduce *TacTILE*, a novel toolchain to more easily create tactile overlays with audio annotations for arbitrary touchscreen graphics (*e.g.,* graphs, pictures, maps). The workflow includes: (i) an annotation tool to add audio to graphical elements, (ii) a fabrication process that generates 3D-printed tactile overlays, and (iii) a custom app for the user to explore graphics with these overlays. We close with a pilot study with one blind participant who explores three examples (*floor plan*, *photo*, and *chart*), and a discussion of future work.

CCS Concepts
• Human-centered computing ~ Accessibility technologies

Keywords
Blind users; visual impairments; tactile overlays; 3D printing; accessible graphics; speech; touchscreens.

1. INTRODUCTION
While mobile screen readers have improved access to touchscreen devices for people with visual impairments, graphical information such as maps, charts, and images are still difficult to convey and understand. One solution is to employ physical overlays that are placed on top of the screen, providing tactile information and constraining input to only specific locations [1,4,6,7]. The *Talking Tactile Tablet* [5], for example, allows users to place tactile sheets (*e.g.,* made from swell paper) on top of a tablet that can then sense a user's touches. *LucentMaps* [2] uses 3D-printed tactile maps with embedded capacitive material that, when overlaid on a touchscreen device, can generate audio in response to touch. Finally, *Touchplates* [4] employs physical overlays with cutouts that can be recognized by a touchscreen device and may be extended to domain-specific tactile graphics (though the focus was on input such as keyboard guides).

An important limitation with these tactile overlay approaches, however, is scalability: each graphic (map, chart, image) requires its own custom overlay and complementary audio annotations. These are typically not easy to create. A related solution to this scalability problem—though not focused on touchscreen overlays—is Façade [3], which allows blind users to take a picture of a smooth appliance interface (*e.g.,* microwave keypad) and semi-

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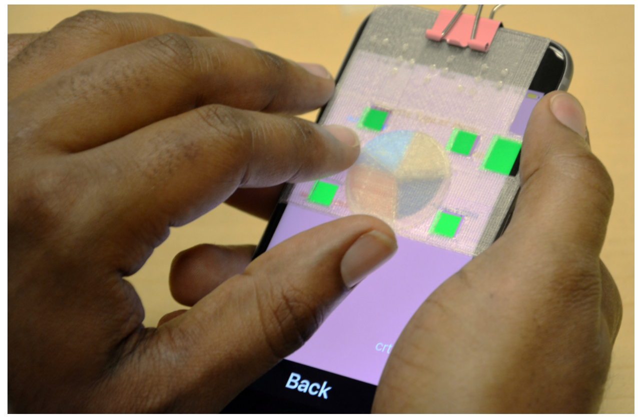

Figure 1. A blind user using an overlay to explore a pie chart on a phone. The cutouts (in green) allows the user to interact with the touchscreen and hear relevant audio descriptions at those locations.

automatically generates a 3D-printed guide to place on the interface, including braille in place of the original printed text. However, Façade is limited to relatively simple appliance interfaces and does not include audio annotations.

In this poster paper, we introduce *TacTILE*, a novel toolchain to support the creation of audio-annotated 3D-printed tactile overlays for touchscreens. TacTILE includes (i) an annotation tool to add audio to graphical elements, (ii) a fabrication process that generates the 3D-printed overlays, and (iii) a custom app for the user to explore graphics with these overlays. As initial work, each pipeline stage is preliminary—*e.g.,* the tactile overlays are generated manually rather than automatically—but our ultimate vision is to dramatically lower the barrier to generating tactile overlays with audio annotations for touchscreen applications. We close with brief results from a pilot study with one blind participant and discuss future work.

2. PROTOTYPE TacTILE PIPELINE
We have focused on three areas thus far: (i) building a GUI-based annotation tool that allows adding audio to the touchscreen element(s) exposed by the tactile overlay; (ii) creating a fabrication process to generate 3D-printed textural overlays with cutouts from 2D graphics; and (iii) implementing an iOS app that allows users to interact with the audio-annotated tactile overlays (Figure 1). The first two stages currently require a sighted user, after which a blind user can download the design to print and load into our custom app. We envision that, ultimately, the second stage will be automatically executed and also be accessible to blind users.

2.1 Annotation Tool
To support the ability to add audio recordings to graphics, we implemented a GUI-based annotation tool using *Processing*, *Minim*[1], and *ControlP5*[2]. In this tool, a sighted user can load an

[1] http://code.compartmental.net/tools/minim/

[2] http://www.sojamo.de/libraries/controlP5/

image by clicking the 'LOAD' button. Annotations are added by clicking the 'TAG' button, placing a rectangle (which represents the interactive cutout), and linking to a pre-recorded audio clip button (Figure 2a; the active annotation is shown in green). While we envision directly embedding the audio into the graphic file as metadata for flexible reuse, we currently link to the external file which is used in our custom app later.

2.2 3D-printed Tactile Overlay

The second step in the process is to design the tactile overlay both to convey graphical information through the 3D print (*e.g.,* via textures, raised lines, *etc.*), as well as to allow access to the audio annotations via cutouts in the print (Figure 2). Overlays are composed of three parts: the name of the overlay in braille, the 3D-printed tactile elements representing the underlying graphic, and the audio-encoded cutouts (Figure 2b). As a proof-of-concept, we created the tactile overlays manually: we first generated a 3D model from the 2D graphic using *Image to Lithophane*, an online sketch-to-3D model tool (http://3dp.rocks/lithophane). We then used *Rhino* (rhino3d.com) to create the braille name and cutout regions for the audio tags. Multiple 3D-printed layers are used to distinguish foreground and background, especially for photos, in the overlay. Ultimately, we envision that our toolchain will do this automatically and allow the user to better customize the tactile elements.

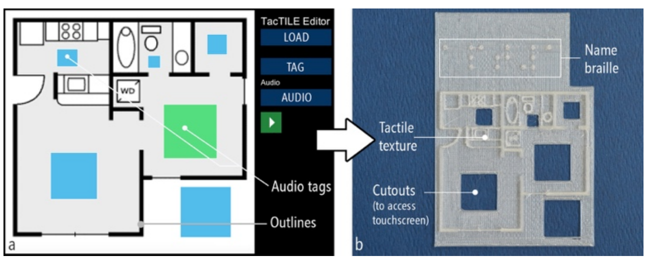

Figure 2. Converting a floor plan from 2D graphic to 3D-printed tile: (a) the annotation tool; (b) 3D-printed tactile overlay.

2.3 Interactive App

The third step employs our custom iOS app. Within the app, the blind user can use the tactile overlay with the app at any time by placing and aligning it at the top of the touchscreen and dictating the name (based on the braille). Interaction involves exploring the tactile overlay by touch and activating the pre-encoded audio annotations by tapping touchscreen areas exposed by the cutouts.

3. PILOT USER STUDY

As an initial pilot study to assess the usability of the interactive overlays created by our workflow, we designed six overlays in three graphical categories for an iPhone 6S sized device: two floor plans, two charts (pie and bar), and two photos (people and scenery). We recruited one male volunteer (39 years old; born with glaucoma and cataracts) who is proficient with screen readers and braille. The study session took ~1.5 hours. The participant was asked to explore the six graphics using the tactile overlays and our iOS app and to describe the details of each graphic. We then solicited open-ended concerns, suggestions, and comments on the overall experience.

Overall, the participant held a positive attitude toward the overlays and our app. First, he could correctly orient the tactile on the touchscreen. Then, he could identify major embedded information, such as graphical objects' spatial details in the floor plans and charts, but missed some details such as people's facial expressions in the photos. Except for the distracting guide lines in the bar chart, charts were reported as easiest to understand. Similar to [4], the participant suggested that cutout shapes other than rectangles might indicate different types of content or audio annotations. Also, the participant felt that some cutouts were too small, so future tools should limit sizes. Extending from prior work [5], standardized symbols or commonly used graphics were preferred rather than complex embossing on the overlay. For example, a simplified tree symbol can be used in photos instead of the current engraved replication of a real tree. Additionally, he suggested that it could be useful to receive feedback not only on the location being touched, but also about the surroundings. For example, touching a bedroom on the floor plan could also describe that the bedroom is to the left of the living room, providing more context.

4. CONCLUSION AND FUTURE WORK

Building on [2] and [4], we combine auditory feedback and 3D-printed tactile overlays to enhance the accessibility of touchscreens, particularly for graphical data. While each of these two components has been explored in prior work, our primary contribution is in designing a reusable workflow, called TacTILE, that enables the creation of audio-annotated 3D-printed tactile overlays for accessible graphics. In future work, we plan to (i) support different types of auditory feedback (*e.g.,* data sonification) using the cutout shapes; (ii) improve the algorithm for tactile overlay generation with standardized graphics; (iii) automate the generation of the physical overlay with braille and cutouts in a standalone program; and (iv) provide feedback on what parts of the graphic have already been explored so that the user can ensure they have covered all areas.

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