An Approach to Last Meter Problem: Designing and Deploying Low-Cost, Custom Fabricated Interactive Tactile Tiles for Navigation and Spatial Awareness

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ABSTRACT

Independent mobility in indoor environments remains a challenge experienced by people who are blind or visually impaired. The current techniques are capable of navigating with accuracy up to 5m, however, are not capable of robust navigation and spatial tasks in the 2-3 meter range. We frame this problem as the "last meter problem" and propose our solution catered towards addressing this issue.

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We propose an alternative approach of augmenting the environment with custom made interactive tactile tiles. Our tiles are pressure sensitive and can provide orientation and audio feedback for navigation. We envision augmenting an indoor environment with such tiles to enable spatial tasks for visually impaired users in the last few meters. Recent advances in rapid prototyping technologies like 3D printers have enabled end-user fabrication of such tiles and could provide a potential avenue to addressing spatial awareness and navigation issues in the last meter.

CCS CONCEPTS

• **Human-centered computing** → **Accessibility technologies**.

KEYWORDS

navigation, indoor mobility, fabrication, tactile haptic cues

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INTRODUCTION AND RELATED WORK

Navigating in unfamiliar environments has always been challenging, especially for people who are blind. Blind people may rely on mobility trainers to help them familiarize an environment and are then able to navigate independently. For new or unknown places, especially when there is no time to familiarize with the environment, it is often difficult to navigate without assistance. There are also potential safety concerns with navigating independently in an unknown environment. Physical cues that help a sighted person are often inaccessible for a blind person. As a result, spatial awareness of the environment is also challenging. Recently, a wide variety of assistive technologies have attempted to solve these problems using proximity sensing. For instance, Wifi signals [3] can be detected by a user's phone to estimate their position. However, the distribution of Wifi access points are not uniform and coverage at intersections are often hard. Similarly, IMU based approaches exist, such as dead reckoning [2], that can estimate a user's position based on previous movement. The accuracy of these IMU based approaches have been shown to degrade over time. Finally, active RFID tags [6] and BLE beacons [4] can be installed in an environment and a person carrying an RFID/BLE reader (or personal device) can then be directed to a destination. However, this approach relies on signal strength and can give only proximity information until last few meters (up to 5m). Most recently the BLE beacons approach [1] has been used for turn-by-turn navigation and has showed some promise reducing the distance to the last 1.5m.

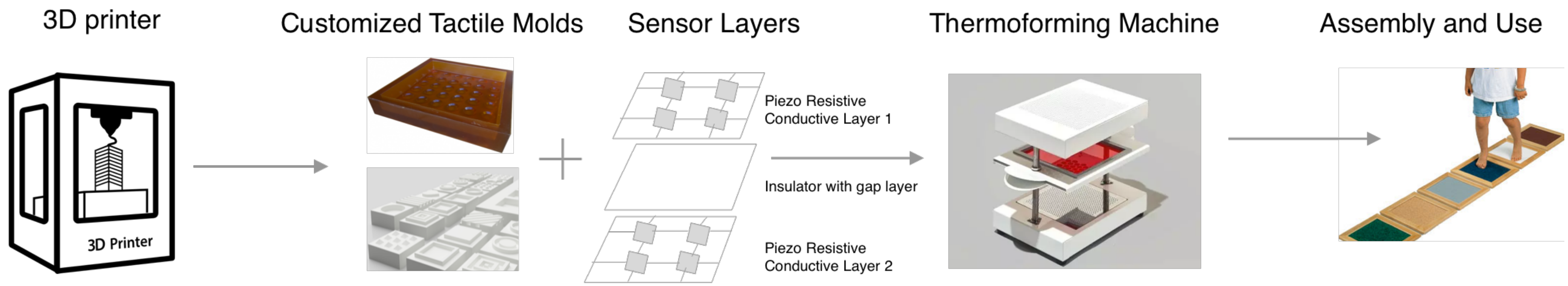

Figure 1: Illustrates our process to make Interactive Tactile Tiles. First, we begin by using a 3D printer to build custom molds with a wide variety of tactile patterns. Then we combine these tactile models with a pressure sensitive layer made with conductive plastics and form our sensor's layers. A user can combine mix match any number of sensors layers with 3D printed molds to fabricate as many tactile tiles as they want. Finally the user can assemble the tiles, install it and interact with them tactually.

A majority of these solutions for indoor navigation and spatial awareness have often failed in guiding blind people until the last 2-3 meters since they have all relied on proximity sensing or on signal strength, which is highly variable and heavily influenced by the construction of the building. These approaches, therefore, have low accuracy in the final stretch of navigation. We call this the "last meter problem". We argue that the last meter is crucial for spatial awareness since many tasks we perform are located in the last few meters. For example, a user may need to walk up to a projector/board in unknown room, switch on lights in room, find where the trash bin is located, etc.

OUR SOLUTION: LOW-COST, RAPIDLY FABRICATED AND DEPLOYABLE INTERACTIVE TACTILE TILES TO AUGMENT THE ENVIRONMENT

One approach to providing spatial guidance could involve embedding tactile cues in the environment. Hence, in this project we introduce an approach to rapid and low-cost fabrication of custom tactile tiles that can be deployed around the environment. Furthermore, the tiles are interactive i.e, the tiles are pressure sensitive, can track users orientation, and can give audio feedback as they walk on the tiles. Similar to outdoor tactile pavement solutions, various tactile markings can be embedded and when users step on these tactile cues, spatial information of the surroundings can be rendered through audio. Our approach is inspired by the successful paradigm of tactile pavements that are widely available outdoors for navigation of the visually impaired. Recent advances in rapid prototyping technologies like 3D printing has paved a way for end-user fabrication of such tiles and can be utilized to augment the environment. Details on how to fabricate such tiles can be seen through imagery in Fig 1.

First, we begin by printing a customized tactile mold, the tactile marking in the mold can be custom designed and each cue could convey some meaning to the user. After printing the mold, we assemble the sensor layers made of conductive plastic with specific patterns for forming a pressure sensing array as show in Fig 1. The sensor's layers are sandwiched with insulation material with sufficient gap. Next, we can assemble the sensor layers along with the mold in a theromoforming machine to pattern out our interactive tactile tiles. Note that once a mold is made, any number of tiles can be made with the only cost being that of the inexpensive conductive plastics.

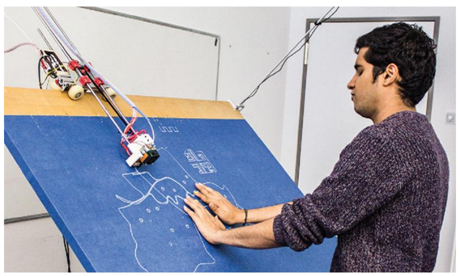

Figure 2: A haptic device for rendering tactile content towards blind users using 3D printer. The device can be used for sense-making or spatial awareness tasks

AUTHORS BACKGROUND

The primary author of this position paper has expertise in building haptic devices and tactile material technologies. Their previous project, Linespace [5] looked at how to help blind users make sense of spatial data by re-purposing a 3D printer (Fig 2) for rendering spatial information like maps, pictures, etc. on demand. We are specifically interested in using advances of rapid prototyping technologies such as 3D printing, desktop thermoforming, etc. towards designing accessible technology. Similarly the other authors have investigated a wide variety of tangible computing projects towards designing assistive technologies. These include building tactile representations of color for inclusive tangible games [7].

OPEN CHALLENGE: SPATIAL AWARENESS IN "THE LAST METER"

A wide variety of indoor navigation technologies have been proposed, however their accuracy and robustness in the last few meters remain poor. One critical challenge to be solved is how to provide for spatial awareness and navigation in the last few meters. For instance, how to help users query for spatial information? e.g., How to locate objects in a room?, etc

Design space of tactile cues for indoor navigation and spatial understanding

Tactile patterns can be custom created using a 3D printer mapped to spatial landmarks. However, the design space of tactile cues and understanding of interacting with such tactile cue using foot remains to be studied. What perceptual patterns could be exploited? How to design for fast and efficient understanding of tactile cues, specifically catered towards navigation, is an open challenge.

How could tactile tiles be seamlessly integrated into the indoor environment?

While tactile marking and guidance surfaces are useful for visually impaired users, such objects may cause issue for sighted users. Hence, we may need to think how to integrate more seamlessly with the environment. Also, safety and stability of the surfaces over time in a specific environment is of concern.

What interactions and input modalities are appropriate for querying spatial information?

While pressure as an input modality could be easier exploited as users are already stepping on tiles, other forms of interaction could be combined for spatial querying. For instance, pointing and pressure input could be combined to enable spatial querying of the entire surrounding. Similarly, another modality to be explored could be speech and orientation (to obtain data from the pressure array).

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