Labeling Systems for 3D Printed Maps for People with Visual Impairments

Matt Mendez and Dr. Thomas Pingel

Department of Geographic and Atmospheric Sciences, College of Liberal Arts and Sciences, Northern Illinois University

Northern Illinois University

Overall Objective

This project uses laser scanning and drone-based photography to develop interactive, 3D printed tactile maps for people with visual impairments.

We build upon the long tradition of cartography for the blind (*Ungar et al., 1993; Ungar et al., 1997*) by enhancing audio feedback and labeling (*Rice et al., 2005; Schito and Fabrikant, 2018; Wang et al., 2009*) using computer vision based approaches combined with open source data repositories such as OpenStreetMap *(Haklay and Weber, 2008).*

Research Question

How can 3D printed tactile maps combine audio with user generated geographic information to allow the visually impaired to more easily learn about their environment?

Previous Technology

Microcapsule paper uses alcohol that expands when heated, resulting in a raised surface in the specified areas.

Embossing is a familiar method that creates raised and/or lowered relief images into the paper. It is somewhat limited in that the height differences are minute and confusion can easily occur.

Touch Mapper allows the user to specify areas to print using OpenStreetMap. Simple, generalized 3D maps can be ordered or printed yourself.

Evaluation Criteria

One of the most important criteria is ease of use. Interaction with the map should be intuitive and require little to no training. We wanted the interaction requests to have a strong tactile component. It should also be easy to update, manage, and deploy these systems. Costs must be kept to a minimum to keep the system affordable.

In addition, multiple levels of information should be supported, going beyond just the feature name. The labeling system should be useful on a variety of tactile maps (such as those produced by Touch Mapper), not just ours.

Implementation Methods

PenFriend

This system uses a pattern of micro-dots and a paired pen "reader" that allows users to record and playback personalized voice messages for each sticker. The intuitive use of a pen-shaped object allows for a connection between the user and the map.

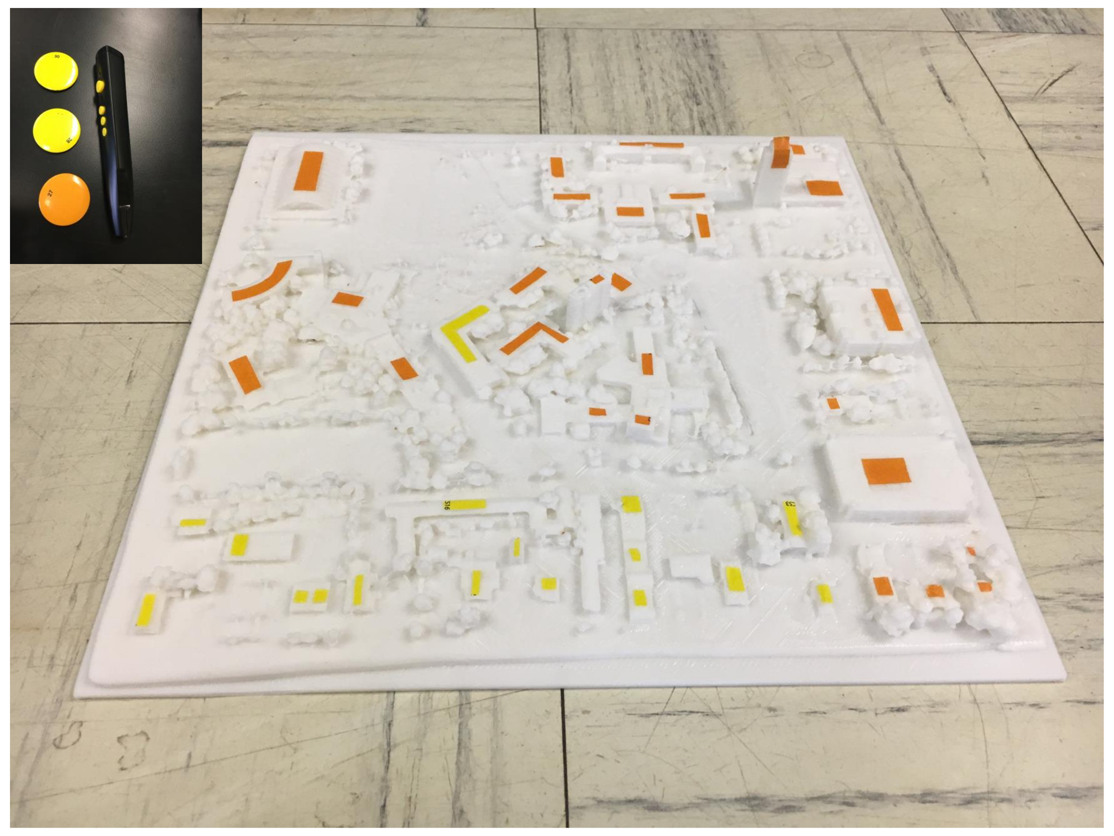
QR Codes

Codes link to existing or custom-tailored websites for each building, providing information for both the visually impaired and others. A text-to-speech engine reads the information through the user's own mobile device. This method compliments an organization's existing web-based Americans with Disabilties Act compliance efforts.

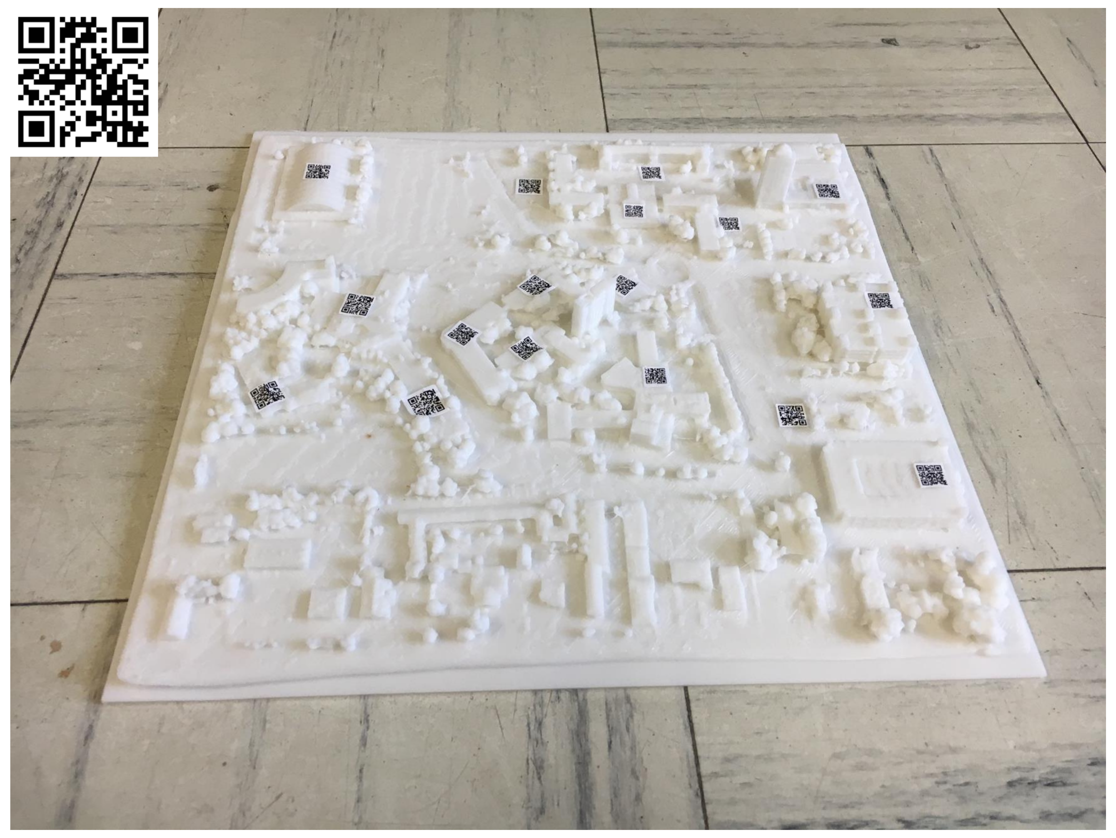
Camera-based

This method combines the ease of use of the PenFriend with the vastly superior information embedding abilities of the QR code. A standard laser pointer is used to "paint" a location on the map. The camera detects only this point, determines its coordinates in relation to the map, and converts them to geographic coordinates. Information is then pulled from OpenStreetMap (OSM) - a real-time, open source repository of geographic information. Place names and additional information are then read aloud to the user through a text-to-speech engine.

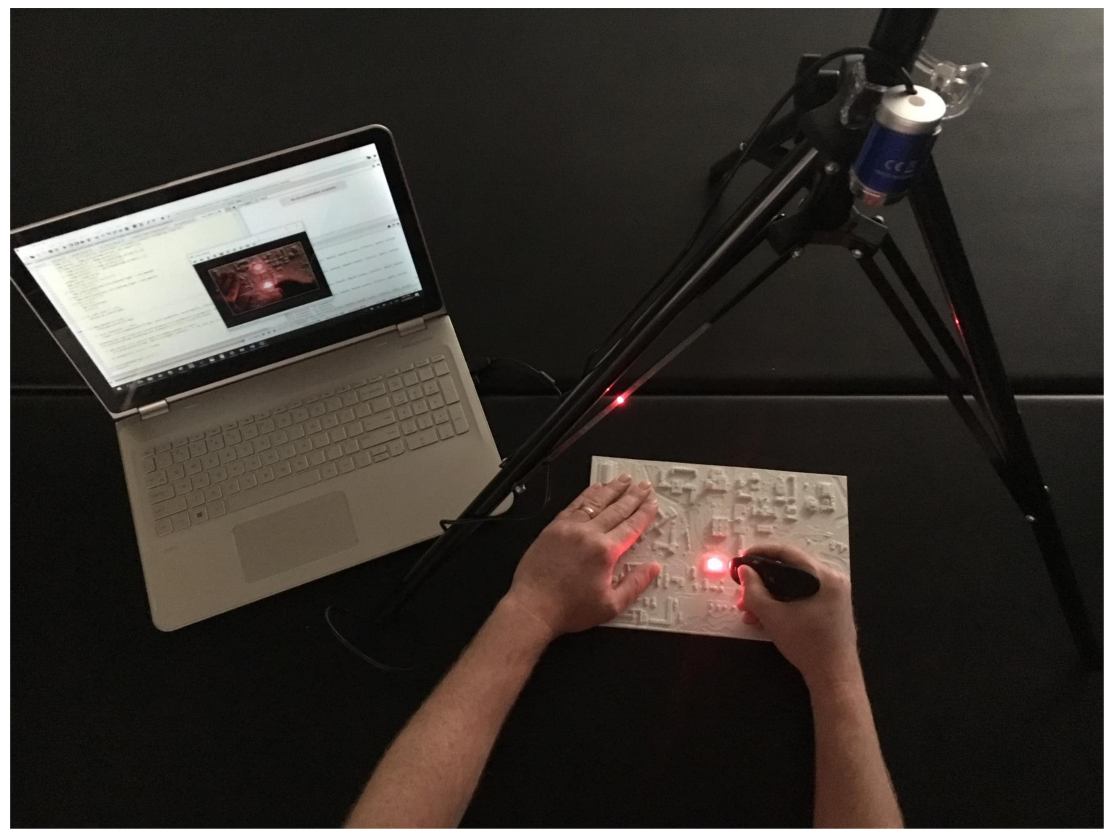
OSM provides detailed information about nearly any feature in the environment, including buildings, streets, walkways, entrances and exits, bike paths, and traffic crossings. It features a well-developed tagging system, supporting things like public transit use, navigation assistance, and other issues of mobility.



The PenFriend approach allowed for custom-shaped stickers to be applied.



QR codes created a higher information ceiling, allowing linking to websites.

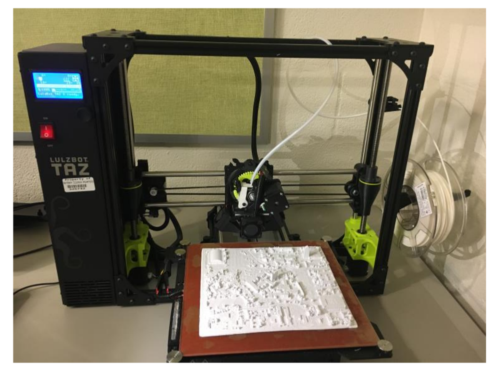


Camera-based laser recognition in action. Instantly extracts place names and building information from OpenStreetMap.

	PenFriend	QR Code	Laser Pointer	Gesture
Advantages	▪ Reusable stickers ▪ Simplicity ▪ Custom voice messages ▪ Can custom-tailor sticker shape to building	▪ Can open multiple media formats including website ▪ Easily generated ▪ Can be scanned with any smartphone	▪ Can hold like a pen ▪ Can use with any map tile ▪ Pulls existing information from OpenStreetMap ▪ Area can be poorly lit ▪ Highly responsive and customizable	▪ Use of intuitive gestures such as pointing and making "OK" sign ▪ User does not need any hardware ▪ User can feel map surface while pointing
Disadvantages	▪ Info stored locally ▪ Can't pull data from external sources ▪ Need device to make use of map ▪ Area must be well lit	▪ Need smartphone to use ▪ Codes have size limits before becoming unscannable ▪ Cluttering issues when scanning ▪ Area must be well lit	▪ Potential for difficulty placing laser on desired building ▪ Must keep hand from blocking laser from camera	▪ Area must be well lit to detect hands/fingers ▪ Specialized equipment required ▪ More error prone than laser pointer method

Advantages and disadvantages of each implementation method.

How are the maps made?

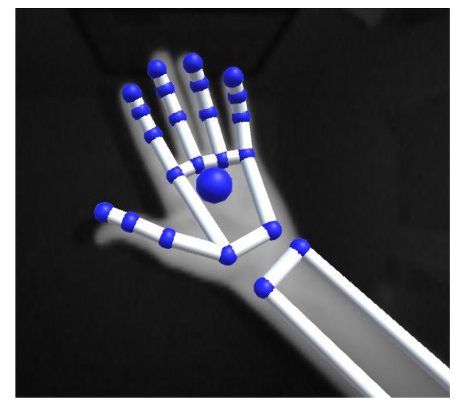


- Buildings are scanned with a drone, and the images from an onboard camera are combined to make a point cloud using state of the art software.
- The point cloud is processed to create a digital model. Customized algorithms control what features are retained. Avoiding too much complexity in the scene keeps the map intelligible.
- The model is 3D printed. Each tile takes approximately 15 hours to print.

Looking Forward

Camera-based gesture recognition is the most advanced method of interacting with the 3D map tiles. We are exploring the use of the LeapMotion device, which tracks hand movement at the tabletop scale through infrared sensors. This inexpensive device is widely used in other Human Computer Interaction projects. In this way, the map user doesn't need a physical device at all, but can query the map using gestures, perhaps combined with speech.

So far, we have experimented with maps on the local scale (e.g., a college campus) to aid local understanding and facilitate navigation. However, this technology could be easily applied to larger extent maps so that users could learn about global scale human and physical patterns.



LeapMotion: making use of infrared cameras and complex algorithms to generate the location of arms/hands/fingers in a 3D space.

References

- Haklay, M., & Weber, P. (2008). Openstreetmap: User-generated street maps. *IEEE Pervasive Computing*, *7*(4), 12-18.
- Rice, M., Jacobson, R. D., Golledge, R. G., & Jones, D. (2005). Design Considerations for Haptic and Auditory Map Interfaces. *Cartography and Geographic Information Science,32*(4), 381-391. doi:10.1559/152304005775194656
- Schito, J., Fabrikant, I., S. (2018). Exploring maps by sounds: using parameter mapping sonification to make digital elevation models audible. *International Journal of Geographical Information Science, 32*.
- Ungar, S., Blades, M., & Spencer, C. (1993). The role of tactile maps in mobility training. *British Journal of Visual Impairment,11*(2), 59-61. doi:10.1177/026461969301100205
- Ungar, S., Blades, M., & Spencer, C. (1997). Strategies for Knowledge Acquisition from Cartographic Maps by Blind and Visually Impaired Adults. *The Cartographic Journal,34*(2), 93-110. doi:10.1179/caj.1997.34.2.93
- Wang, Z., Li, B., Hedgpeth, T., & Haven, T. (2009). Instant Tactile-Audio Map: Enabling Access to Digital Maps for People with Visual Impairment. *Proceedings of the 11th International ACM SIGACCESS Conference on Computers and Accessibility,*43-50. doi:10.1145/1639642.1639652