Universal Design Interactive Multisensory Models

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ABSTRACT

The Multisensory Interactive Model (MIM), developed by Touch Graphics Inc. and the IDeA Center, provides an immersive wayfinding experience for all. It offers a combination of audio, visual, and tactile output so sighted, low vision, and blind individuals can all use the same device to learn about an unfamiliar environment. The system demonstrates that public cartographic tools can be designed to be usable by almost anyone, creating a truly universal navigation and orientation device. Several MIMs were recently constructed and evaluated including installations at the Carroll Center for the Blind in Newton, MA, Chicago Lighthouse, and Perkins School in Boston, MA. These installations provided opportunities to identify and test strategies for communicating key wayfinding and orientation concepts under different environmental conditions with different user groups. Through iterative user testing, the design team evaluated modes of interaction and information display and identified key improvements for the next installation. This process allowed us to develop an improved wayfinding tool that is highly responsive to the specific needs of diverse audiences, promotes social interaction, and supports inclusion for the broadest population.

Keywords

Multisensory, Inclusive, Universal, Tactile, Interactive, Wayfinding

INTRODUCTION

Interactive devices are now ubiquitous in our daily lives. These devices have reduced previously time consuming tasks to a single button click, swipe of a card, touch of a finger, or hand gesture. Performing these tasks on devices rewards us with tangible results. For example, pushing the buttons on a coffee maker produces a hot drink, navigating the card slot and push buttons of an ATM dispenses money for use, while touching buttons on an iPod provides entertainment content. For the majority of the population, these routine tasks are carried out with little effort. However, for many individuals, these tasks are relatively difficult because of limitations in their physical, sensory or cognitive capabilities.

Whether it is through direct experience or the use of an interactive device, one of the most frequently performed tasks is obtaining wayfinding information. So, it is not surprising that there is an abundance of interactive tools and systems available to help with spatial orientation and navigation of the environment. These devices include compasses on smart phones, GPS navigation devices, and interactive maps found in transit stations, malls, and other large facilities. Most of these devices provide the user with real time information that is updated regularly. Although the abled-bodied population finds them quite useful, those with limitations of vision do not find them so helpful. This paper focuses on an ongoing research and development project of the Center for Inclusive Design and Environmental Access at the University at Buffalo and its business partner, Touch Graphics, Inc. Together, the two organizations developed an interactive device for installation in buildings, campuses, and urban areas that provides wayfinding information for users of all abilities. Although the device is a stand-alone product at present, we anticipate applications in the future that will make it an integrated element in a complete wayfinding solution.

Whatever our method of traveling: walking, driving, or bicycling, we're constantly finding our way in the environment. There are three primary activities in wayfinding: orientation, route navigation and destination identification. Conventional tools used for orientation include compasses, "you are here maps" and scale models. Navigation tools include use of portable maps and route instructions (verbal or written). Conventional room signs and landmarks are used to confirm one's destination. For the sighted population, it is fairly easy to process information provided by the three types of tools. But blind and visually impaired people use additional information than the conventional tools usually provide. For example, unable to read a printed map, a visually impaired traveller will rely more on verbal instructions, and, such instructions need to focus on non-visual information like the number of paces from point to point, audible landmarks, ground or floor textures, smells or even wind patterns. Wayfinding tools specifically for blind and visually impaired travellers have been developed, including tactile maps and models, tactile signs, talking signs, and talking GPS systems.

Assistive technologies, or devices developed specifically for people with disabilities, however, generally lag behind mainstream commercial products (Subryan, 2012). This is especially evident in wayfinding technologies for people with vision limitations. Assistive technologies for navigation have been around for many years, however, they are still quite expensive, difficult to obtain, and often based on legacy IT platforms. New operating systems with tactile interfaces are now introducing accessibility into mainstream wayfinding products. For example, the iPhone's voice over command feature allows blind and visually impaired users to use the device easily by changing a single setting. However, there are still significant limitations to overcome. The first is the lack of GPS reception indoors. The second is that the information provided for the general user of a navigational device does not always help the non-visual traveller. For example, visual landmarks like stores in a mall are not useful for people who cannot read them. Tactile maps and models, on the other hand, could provide universal benefits that are valuable to all users, not just people with visual impairments.

Existing Research and Evidence

Tactile maps are an essential part of wayfinding for those who experience vision loss. Research shows that traditional tactile maps and small-scale models promote better comprehension and enhanced knowledge of relatively unfamiliar outdoor environments for the blind (Blades et al., 1999). A comparative study on the differences using an interactive audio tactile map and verbal directions to find a specific location determined that blind or visually impaired individuals had a better chance of navigating by using tactile interactive methods than by relying on verbal directions from a bystander (ArditI et al., 1999). In addition, a 1998 study by Espinosa et al. on the effectiveness of various wayfinding methods such as direct experience, verbal description, and cartographic representation established that the participants' spatial knowledge was better with the use of tactile maps (Espinosa and Ochaita, 1998). And in Ungar and Blades's study of children's abilities and how they orient themselves with and without the use of tactile maps, findings showed that through direct and indirect examination the use of tactile maps worked in aiding the children's performance (Ungar and Blades, 1994).

Information on tactile maps may be either simple or complex but should always be legible and intuitive. Simple maps may include just a set of raised lines depicting street routes; while a complex map may be composed not only of streets, but also of buildings, landscape features, and symbols. Permanent maps should be designed so that the end user is able to easily recall information even after stepping away. For this reason it is important that tactile maps not be cluttered. A substantial body of research exists that examines the layout of information on tactile maps. Bentzen (1983) points out that when designing this type of map consideration should be focused on "information content, scale, size, choice of symbols, information density, labeling, and indexing." Designers should exclude any unnecessary information but at the same time should avoid adding too little. Users of tactile maps are often able to comprehend individual symbols, but too many symbols may cause difficulty in performing simple route mapping tasks (Bentzen, 1983). Additional empirical research has focused on the 'shape recognition accuracy and speed and accuracy of locating shapes' (Berla and Butterfield, 1977), 'legibility and meaningfulness of symbols and features' (Lambert & Lederman, 1989), 'roughness of textures' (Lederman, 1983), 'smooth and rough substrates' (Jehoel et al., 2005), and 'fingertip sensitivity to object height thresholds' (Johansson and LaMotte, 1983).

Tactile maps may be categorized into two types: 'orientation' maps that provide large amounts of information and 'portable' maps that are often smaller for personal use (Harder and Michel, 2002). Orientation tactile maps are intended for long-term installations and so are made out of strong, durable materials. This type of map may be constructed using a wide range of methods including moulded plastics, etchings in magnesium or bronze, or embossing techniques on card stock or metal foil (Horsfall, 1997) (Figure 2). Portable tactile maps, on the other hand, are constructed for temporary use. They are usually made out of disposable material such as paper with embedded plastic fibers (swell paper) that expands when heat is applied to locations onto which images have been drawn or photocopied (Horsfall, 1997). Portable tactile maps are often distributed to end users at schools, universities, and museums. Recently, newer technologies have become available that can further the development of tactile maps. These technologies are allowing designers to create new user experiences and interactions to benefit a more diverse user population.

Existing and New Technologies:

We used several technologies, all available in general commercial use, to construct the MIMs. The most important was the use of 3D printing. Recent advances in rapid prototyping using 3D printing have significantly reduced the cost of producing durable scale models with more relief and detail than conventional tactile maps. Most 3D printers generate durable models in acrylonitrile-butadiene-styrene (ABS) plastic, a commonly used plastic in manufacturing. Second, we used a technology that senses and records the presence of touches. The use of touch enabled personal gadgets like mobile phones, e-readers, and touch tablets is ubiquitous. Many companies are now producing large interactive touch based panels for public wayfinding and information. Although, these maps are very effective, most can only be used by sighted individuals due to the lack of tactile content. Touch Graphics, Inc. designed its own multichannel touch base sensing module for use in the MIM. Third, we incorporated a projected display. Digital projection is a well-known technology that is available in many forms, including front, rear, overhead, and bottom light projection. Front and rear projection is often used in interactive displays that are controlled remotely; while overhead and bottom light projection are used most for games and digital drawing by allowing the user to actually touch the screen. The use of projection on the MIMs allowed dynamic information display such as text and image to be overlaid onto it.

Coupled together, touch interaction, 3-D digital models, and projected displays allowed us to create a multisensory device which provides wayfinding benefits to a wide range of users through a single interface. The ongoing iterative process of the project resulted in unique features for each MIM installations. It allowed us to improve the usability of the model and implement new features which further enhanced the overall experience of the user with each new installation.

Development of the Multisensory Interactive Model

The process of orienting new students to a campus layout is often difficult. It is even more difficult when the student is blind or has a vision-impairment. Traditionally, schools for the blind have sought to support incoming students by providing a ‘direct experience’ tour of the campus with the help of an orientation and mobility specialist (Blades et al., 1999). While this technique has proven effective, particularly for students attending large campuses, it does not support the goals of independence, self-sufficiency, and self-fulfilment that are fundamental to this type of learning environment. Recently, some schools for the blind have sought to supplement the direct experience approach with the introduction of tactile maps. These maps are made available on a personal, portable scale and reinforce the learning goal of autonomy. Although the potential offered by tactile maps is great, the actual product is often prepared very quickly, resulting in a crude mock-up of the campus that gives little meaningful information to the user.

A few years ago, with the goal of finding a more inclusive method of orientation and wayfinding, the IDeA Center and Touch Graphics, Inc. collaborated with the Carroll Center for the Blind in Newton, MA to design the first prototype interactive model to aid navigation on their campus. Called the Carroll Center Touch Model (MIM1), this wayfinding device was developed by combining three dimensional rapid prototyping techniques and touch base sensing technologies into a simple, intuitive interactive tactile model (Figure 1). The model was based on haptic interaction, and students learned to navigate the Carroll Center campus through a combination of touch and audio responses. The interactive model was designed so that while exploring the model with their hands, the computer, sensed the touch of the users, and responded by offering helpful audio descriptions and wayfinding information. A simple cursor control allowed users to drill down for more information or use the model in a goal directed mode to find specific buildings and other features.

Design, prototyping, and production of MIM1 lasted nearly six months. As part of this development process, the team created a portable touch sensor package that simplified and modularized the installation and control over sensors. Most of the features on the Carroll Center Model are touch sensitive. When a user approaches the model, he or she can activate it by touching anywhere. If the user touches a part that is audio enabled, a recording describes the feature that has been touched. The audio-enabled features on the model are controlled by a cursor control with three buttons; a round main button, and two triangular directional buttons. If the user presses the main button, he or she will hear a recorded introduction to the Carroll Center explaining how the model is to be used as well as how to access such options as a campus overview and an alphabetical index of destinations (with audio coaching to find places on the model). The audio model is adjustable for individual preferences and hearing capabilities through volume control and pace of voice control. Users can further personalize their experience by adjusting the level of touch sensitivity of the features. We selected and assigned colors designed to improve visibility of features for those users who have some vision and to denote the different building types, i.e. dormitory, administrative, etc.

Figure 1: Carroll Center Multisensory Interactive Model (MIM1)

A brief usability study was conducted on site to evaluate the effectiveness of MIM1. A total of five participants who were either legally blind or visually impaired took part in the study. Each participant was interviewed about their orientation experience at the school and was asked whether they had previously navigated the Carroll Center's campus. Participants then received a 10-minute training session on the use of the model followed by 15 minutes where they could explore the model on their own. After the exploration period, participants were then asked to explain their process of orientating themselves using the model and were asked to find a physical location based on what they had learned from the model. If the participant already knew the location, they were asked to find another location with which they were not familiar. Each participant then attempted to walk from the location of the model to the assigned destination. If the participant could not find the location, they were asked to refer to the model a second time for as long as necessary and then asked to repeat the task. Finally, each participant completed an interview questionnaire that assessed their experience with the model including the performance of audio information, quality of material texture (i.e. grass, roof, pathways, and railings), understanding the difference between street and sidewalk levels, and finding the location of key features such as door entries.

The general consensus from participants was that the interactive model was easy to use and that it enhanced their knowledge of the campus whether or not they had prior familiarity. Participants found that the navigation buttons were easy to use once they had located them on the model. Most of the participants were able to identify distinct textures on the model and were able to identify the differences between landscape, roads and pathways. Students were able to locate various buildings and learned different routes between buildings. According to the Carroll Center orientation and mobility specialist, the multisensory model is a positive addition to their campus wayfinding system and will improve orientation sessions in the future. The only negative feedback from the study was that the audio was sometimes unclear and hard to comprehend. Suggestions for improvement included a request for a more human audio voice.

With a process in place for producing a multisensory wayfinding device, a second version of the model (MIM2) was developed for the Chicago Lighthouse International (Figure 2). However, it provided new challenges. While the model for the Carroll Center is designed as a 3 dimensional single campus model, the Chicago Lighthouse is entirely in one building with two floors. This meant that we had to create two separate models, one for each floor. Other unique challenges included designing a simple floor plan which covered all the essential information for visitors and established a continuous flow between the first and second floor by linking the two models together.

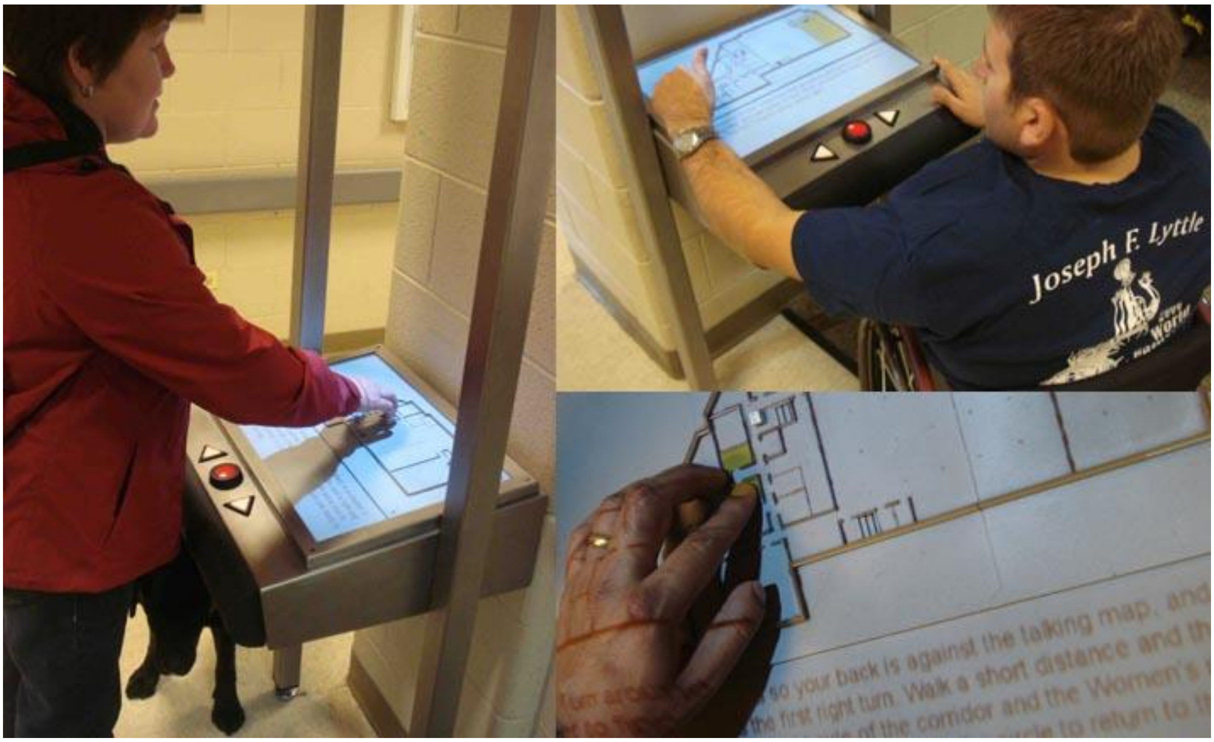

Figure 2: Chicago Lighthouse International Multisensory Interactive Model(MIM2)

The process of making another model allowed us to apply some of the findings from the Carroll Center to improve MIM2. For example, the way the pieces were made on the 3d printer were streamlined, and, the number of individual pieces produced was reduced to decrease the tactile noise (unintentional raised lines and bumps) on the model. Furthermore, rather than painting the ABS plastic prints as in MIM1 to highlight specific building types, a projector was used to project a dynamic display to illuminated key features with color and text. As a user selected a location or an object on the model, the appropriate area lit up, and the same audio was displayed as text at the bottom of the interface (same as the audio). The combination of projected information, tactile 3D printed model, and touch base sensing truly created a universal design wayfinding tool for users.

A usability test was also carried out on MIM2 with a total of twenty individuals including young adults and older people. They included individuals who were sighted, visually impaired, wheelchair users, and totally blind. This gave us a broad range of feedback on both the functionality and aesthetic qualities of the physical design. The same research protocol was followed as MIM1. Feedback from participants highlighted essential information which could further improve the existing model and the design of future models. For example, MIM1 was installed in a location which was relatively quiet, whereas MIM2 was installed in a location that was used heavily. Many of the participants needed to repeat presentation of information because they either couldn’t hear it due of background noise, certain words were muddled, or they didn’t remember all of the information in its entirety. We therefore discovered that a simple repeat function was needed on the device. This would allow the user to remember the information more easily through repetition, especially directions to locations. Furthermore, it would enable the user to learn the device much quicker by eliminating the need to start over. This feature could be easily incorporated with a few simple adjustments in the program. Also, we learned that providing a headphone or headphone jack would improve ease of use in noisy locations.

The research findings indicate that the pathways/corridors on the model should be defined better. Many users couldn't tell that they existed unless they were identified and explained. In particular, the complex system of corridors, which is the main organizational feature of the Lighthouse facility, is hard to understand. In the current design, the parallel walls of the corridor are so close together that the fingertip cannot squeeze between them to touch the bottom of the 4mm wide trough, and so it is not possible to add audio labeling to this crucial feature. These corridors could be filled in and raised above the rooms to which they lead; then the corridors will be perceived as the primary feature of the model distinct from the rest of the plan. The elevator and stairs could be connected to this raised path system as well. This would emphasize them as key landmarks.

Some findings suggest including features that would provide specific benefits to sighted and perhaps low vision individuals. These include providing a projected line of the audio route from the 'you are here' marker to the destination while the audio directions are presented. The text of the audio directions is displayed at the bottom on the model. Sighted users suggested having an option to turn the audio off completely because they prefer reading the text rather than listening to the audio.

Figure 3: Perkins School for the Blind Multisensory Interactive Model (MIM3)

Direct feedback from the participants gave a clear indication that use of the model would be beneficial while working or visiting the Chicago Lighthouse. They found the level of tactile detail on the model as well as the information provided in the descriptions and directions to be supportive. Most of the users felt that the information on the model gave them a better understanding of the overall building. Most users found both the buttons on device and the touch interface very easy to use. After a few minutes of using it, most users understood the main features such as the index of places, index of people, and the settings and were able to figure out how to access and change them. Many participants felt that the model gave them a sense of independence because they were able to learn how to use in a matter of minutes and then use that skill to find a physical location within the building.

A third model (MIM3) was designed, built, and installed at the Perkins School for the Blind (Figure 3). Like the Carroll Center model, this one is a campus model with no interiors. The MIM3 is fully operational and includes several additional features. The three most important are the projection alternative graphic representations of the campus, a refreshable braille display, and a gaming feature that is designed to encourage students to explore the model as a recreational pursuit. Figure 3 shows two different projected images. One is a color-coded image, which produces an image similar to the Carroll Center model. The second utilizes the Google Maps' satellite image. Projecting the image, we believe, is not only less costly but more effective than painting the model because it allows the building owner to modify the image more easily for different populations and uses. It also produces a dramatic and attractive image that engages the user with vision more successfully. A usability study is planned in the near future to learn where improvements are needed.

CONCLUSION

The Multisensory Interactive Models project originated as an experimental prototype to meet the orientation needs of blind and low vision students on a school campus. Today it is a market ready product with the potential for widespread use in more public environments. After a series of intensive studies involving material use, texture conditions, object placement, and technology refinement, Touch Graphics Inc. and the IDeA Center were able to develop the prototype into a fully functional customizable product. Through the use of Touch Graphics' in-house rapid prototyping machines and a flexible manufacturing system, model construction has been simplified and costs reduced significantly from the original design. The evaluation research demonstrated that the MIMs were a significant help to the visitors, students, and staff at the Carroll Center and the Chicago Lighthouse. We expect similar findings at the Perkins School.

The project used the development and testing of an assistive device as a "proving ground" for a universally designed product (see Subryan, 2012). By testing the product with people who have limitations in performance of different types, we learned how to accommodate a wide range of abilities and preferences for the physical model and the software. The next stage of product development will be the design and construction of a model for an environment where most users do not have a disability. We are also exploring development of interfaces with other wayfinding technologies. There is potential for integrating other devices to make MIM's a "base station" for a full wayfinding solution, allowing navigation from place to place and destination verification as well as orientation.

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