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Creating Accessible Science Museums With User-Activated Environmental Audio Beacons (Ping!)

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In 2003, Touch Graphics Company carried out research on a new invention that promises to improve accessibility to science museums for visitors who are visually impaired. The system, nicknamed Ping!, allows users to navigate an exhibit area, listen to audio descriptions, and interact with exhibits using a cell phone–based interface. The system relies on computer telephony, and it incorporates a network of wireless environmental audio beacons that can be triggered by users wishing to travel to destinations they choose. User testing indicates that the system is effective, both as a way-finding tool and as a means of providing accessible information on museum content. Follow-up development projects will determine if this approach can be successfully implemented in other settings and for other user populations.

Key Words: Computer telephony—Blind—Visually impaired—Museum—Accessibility—Way-finding—Audio description.

This article reports on a federally funded research project carried out by Touch Graphics Company that included the design, implementation, and testing of a new approach to making public exhibit spaces, such as science museums, more accessible to visitors who are blind, visually impaired, or otherwise print disabled. The system includes a wireless network of user-activated audio beacons that are triggered through a telephone interface. In the study, visitors navigated the exhibit space using cell phones, independently choosing which exhibit components to move to; when they reached a chosen destination, they listened to audio description of the relevant exhibit content and triggered local events, all with their phones. On completing their museum visit, users were asked to answer a series of survey questions, again using the phone, about their experiences in the museum that day. The hardware/software solution relied on is an innovative combination of existing, proven, and cost-effective technologies. The work may lead to the introduction of a suite of products and services that could eventually be useful in a wide range of applications beyond the first target of making science museums more accessible.

BACKGROUND

People who cannot see well have two separate problems that interfere with their benefiting from many science museum exhibits. First, they often cannot independently find activities within museums, and second, in many cases they cannot see the display or access interpretive or explanatory materials. Many blind and visually impaired persons do not venture into science museums because of a history of frustration. This substantial population of between 4 and 12 million persons (Kirchner & Diament, 1999) is effectively shut out from the self-improvement and entertainment that are central to the mission of most museums (Friedman, 2000). When science museums are public in-

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stitutions, failure to provide access to everyone also raises troubling legal and ethical questions.

Since the implementation of the Americans With Disabilities Act, many science museums have taken steps to improve general accessibility to their facilities; wheelchair ramps and lowered counters are of great help to people with mobility impairments. Captioned videos provide access to this medium for deaf visitors. Recently, museums have begun looking for ways to extend this policy of inclusion to members of the community who are blind, visually impaired, or otherwise print disabled. Solutions to access for this group are much less obvious than the physical requirements of people who use wheelchairs. Nevertheless, practical solutions should be found to eliminate barriers and to ensure that everyone has equal access to these important resources.

Some work has been done in this field. The Talking Signs product, first developed at Smith Kettlewell Eye Research Institute in San Francisco (Bentzen & Mitchell, 1995) and now manufactured by the Talking Signs Company of Baton Rouge, Louisiana, has been deployed at several museums, including the Mashantucket Pequot Museum in Ledyard, Massachusetts. Touch Graphics, Inc., created a Talking Kiosk, which included an interactive, touchable, raised-line map of one exhibit space at the Boston Museum of Science in 1999 (Touch Graphics, Inc., 1999). And in 2000, the New York Hall of Science demonstrated a handheld audio guide system that provided extensive audio description of exhibit offerings (Friedman, 2000).

CONCEPT

In 2001, Steven Landau, a sighted inventor, and Ellen Rubin, an expert in museum access who is blind, collaborated on the first concept for a network of addressable environmental audio beacons that could be controlled by blind or visually impaired museum visitors using cell phones. Inspired by the computer networking technique of sending out an individualized signal and listening for its echo, the inventors nicknamed the system "Ping!" The idea for Ping! was inspired by three simple observations:

1. Most individuals who are blind and visually impaired receive training in Orientation and Mobility (O&M), which teaches them to navigate around local obstacles as they move from place to place. O&M also teaches strategies for keeping track of the relationship between one's current position and a desired destination point, in terms of both distance and bearing. However, it is often quite difficult to maintain awareness of one's position in open space without recognizable landmarks or audio cues.
2. One of the most pressing requirements for wayfinding in complex exhibit spaces is access to overview information about the environment, including knowledge about the general layout and the range of activities available that are relevant to one's interests and intellectual ability, and the proximity of various possible destinations to one's current position.
3. More and more, portable telephones are becoming an essential part of the blind and visually impaired person's traveling kit; the simplicity and familiarity of the tactile interface, the nonvisual nature of phone interactions, and the telephone's low cost and ubiquity make it an ideal assistive device. As usage fees continue to drop and as gaps in reception are filled in, there are good reasons to believe that more and more blind individuals will begin to rely on cell phones (Fruchterman, 2003).

In 2002, the developers were awarded a Phase 1 Small Business Innovation Research Grant from the National Science Foundation. The project called for the installation and evaluation of a fully functional version of the system in the New York Hall of Science (NYHoS) during the first half of 2003. What follows is a report on the experimental design and findings generated in the course of carrying out this work.

FUNCTIONAL OVERVIEW

For the version of the system that was implemented in NYHoS, up to three simultaneous blind or low-vision museum visitors call a toll-free phone number using their own cell phone or a cordless phone lent to them for the duration of their museum visit; callers interact with a computerized human-voice narrator, making choices in response to spoken menu options by pressing keys on their phone or by saying numbers that correspond to choices. Callers choose a personal Ping! attractor sound from a catalog of available chirps, whistles, and other tones that have been specially designed to be easy to use for estimating direction and distance and that are also not distracting or annoying to other museum visitors. Once selected, a sound is removed from the catalog of attractor sounds that are offered to the next user to log onto the system. When the current user leaves the museum or logs out of the system, his or her Ping! sound is restored to the list.

Once they have been assigned a sound, users select a destination that interests them from a list of possible places; the destination list is presented in order from nearest to farthest (in respect to their current position), so that callers have the ability to factor in distance considerations in determining which destination to choose. Then, when they press a designated key, their Ping! sound is sent (via radio signal) to a wireless audio beacon located at the requested destination. They listen for the sound and make their way toward the destination, triggering the sound as often or as seldom as they want to assist them as they navigate, while negotiating local obstacles encountered during travel. The sound occurs at the exact instant that the phone key is pressed, to make it easy to listen for and to get a fix on, even over the din of a crowded exhibit floor.

When users arrive at the desired destination, they are instructed to press a different key, at which point the phone provides audio description of the exhibit content. This includes a description of the physical layout of the exhibit, discussion of the concepts being presented, and directions for interaction. If the exhibit offers other experiences or optional information that has to be requested, this is done by pressing appropriate keys on the phone to trigger local events. For example, at one exhibit on the topic of the size of molecules, sighted visitors step on a scale and touch an icon on a computer display to see their weight, in molecules, displayed on the screen. We added a feature to the Ping! system software that allows a blind or visually impaired visitor to press a key on the phone to initiate the weight calculation, which is then spoken aloud from the exhibit's sound system.

When participants are ready to move on to the next activity or to exit the exhibit, the system allows them to select a new destination (from a new list of possible destinations, again organized from nearest to farthest) and to travel there in the same fashion. If the new destination is far away (more than 20 ft or 6.5 m) from the current position, the computer constructs a "stepping-stone" path that calls for the visitor to follow a chain of audio attractors, indicating arrival at each one by pressing a designated key on the phone. The computer "knows" where the caller is at any time because the caller announces arrival at each destination upon reaching the audio beacon. This approach to location awareness differs from strategies now being developed by other companies, for which GPS-equipped portable computers provide instantaneous position information that is linked to text-based databases of environmental information and descriptions (May, 2003). It can also be used indoors, unlike GPS systems, which currently require direct visual contact with three or more circling satellites.

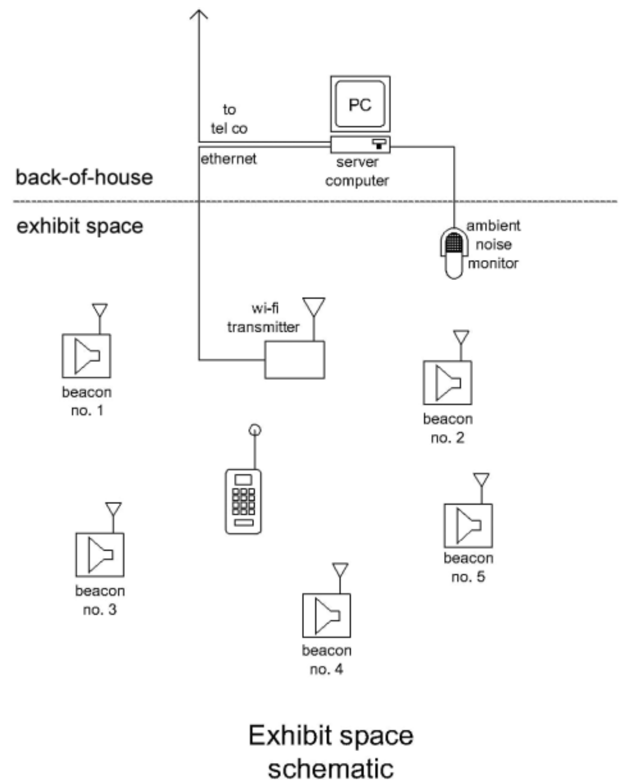

FIG. 1. Schematic diagram showing system components.

At the completion of the visit, the system narrator asks the caller to participate in a customer survey. Survey questions call for either a numerical response (e.g., "Please rate your level of interest in the subject matter from 1 to 5") or a spoken message that is saved to the computer's hard drive. The results of the survey and statistics on which activities are visited and for how long are recorded to a database that automatically produces a record for each user of the Ping! system. Later, we are able to query the database to learn about usage patterns and customer satisfaction.

TECHNICAL OVERVIEW

The Ping! system is based on a new application and configuration of existing, proven technologies. At the most basic level, the system incorporates the following components (see the diagram in Fig. 1).

- A PC outfitted with a computer telephony expansion board (Dialogic's D41/JCT-LS; Intel, Santa Clara, CA). This board handles up to four simultaneous phone callers and connects via

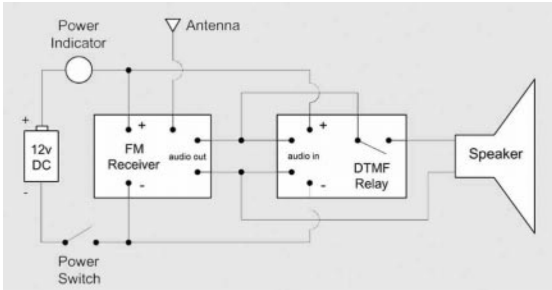

FIG. 2. Schematic diagram of an individual wireless audio beacon. DTMF = dual-tone, multifrequency.

twisted-pair wiring to phone lines installed by the telephone company.

- A software application created with a voice mail authoring system, Pronexus's VB Voice (Ottawa, Ontario, Canada), used as a set of routines and tools for the programming environment, Microsoft VB.net (Redmond, WA). The software controls the system and manages all user interactions and connectivity to the Microsoft Access database. All voice messages are prerecorded human speech (not synthetic speech) for good comprehension of potentially complex descriptions and instructions. Current text-to-speech engines do not adequately permit the precise and nuanced rendering of language that this application demands.

FIG. 3. A photograph of one of the experimental beacons.

- A low-power FM radio transmitter connected to the computer's audio output, with an antenna located in the exhibit area.
- User-owned cell phones or cordless phones lent to visitors from the museum's information desk.
- A collection of wireless audio beacons, housed in compact metal enclosures, at each destination or way-point in the exhibit space (see Fig. 2, a schematic diagram of one beacon, and Fig. 3, a photograph of a beacon). The beacons consist of:
  - a 12-volt DC, 5 amp/hr sealed lead acid rechargeable battery;
  - a radio receiver tuned to the same frequency as the transmitter;
  - a dual-tone, multifrequency (DTMF) activated relay placed in-line with the audio output from the receiver; this device "listens" for an encoded string of tones that uniquely identifies each beacon, and it momentarily closes the speaker circuit upon hearing the correct DTMF code;
  - a low-power audio amplifier; and
  - a speaker.

DESCRIPTION OF THE RESEARCH AND DEVELOPMENT EFFORT

The 6-month undertaking focused on solving a variety of technical and usability issues and culminated in an experimental installation in the NYHoS exhibit space. The NYHoS is an ideal laboratory for the demonstration, because it tends to be noisy; it includes a variety of exhibit station configurations; and some of the exhibits are potentially highly accessible to a blind and visually impaired audience, with plenty of audio, tactile, and olfactory content. NYHoS was also the site of an earlier research project that focused on creating an audio tour for the museum that would be accessible to a blind or visually impaired visitor (the current project builds directly upon this previous work; Friedman, 2000).

Thirteen wireless audio beacons were installed in exhibit casework, and additional beacons were mounted at restrooms, in the cafeteria, and along a route between the exhibit floor and the main information desk in the lobby, through some doors and down a flight of steps, about 300 ft away (see Fig. 4, a floor plan of the museum, showing the route visitors take from the main information desk to the exhibit floor).

A computer server that controlled all system interactions was set up in a secure back-of-the-house location. Audio content, adapted from the museum's existing audio guide program, was digitally

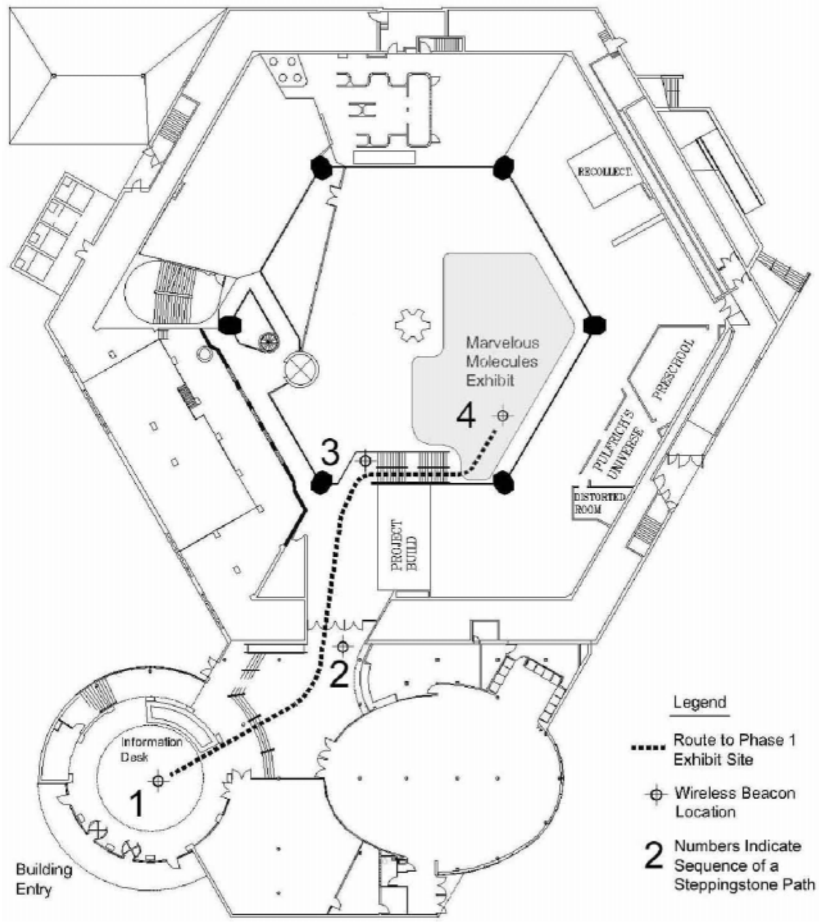

FIG. 4. A plan of one floor of the New York Hall of Science, showing a travel route connecting the main information desk with the exhibit floor. The route included a "stepping-stone" path consisting of start and finish points and two way-points.

recorded and saved to the computer's hard drive as individual phrases that also included instructions for using the system. The experimental design was organized so as to shed light on the system's effectiveness, especially in relation to a set of specific questions that needed to be clarified prior to creating a permanent version of the system.

First, research had to be carried out to study the implications of multiple users accessing the system and moving through the exhibit space simultaneously. From a technical point of view, there are no significant obstacles to accommodating multiple users; computer telephony–based call center equipment and software are designed to handle vast numbers of simultaneous interactions. The research plan called for a system capable of handling four visitors at once, but the user trials included groups of three participants moving through the exhibit space together, and the fourth phone line was reserved for outgoing calls, used when a participant chose to be connected to a live member of the museum staff. A permanent installation could be configured to accommodate many more, but it is still unclear what a desirable target for simultaneous call handling will be. Specifically, we need to know whether two or more users can "ping" their way toward the same destination at the same time without becoming distracted or confused by one another's sounds, and we want to confirm that computer performance does not suffer during periods of high numbers of simultaneous callers.

One of the most interesting and powerful possibilities for the system described here is that multiple-step routes could be followed to destinations that are far away from a user's current position. Assume, for example, that the visitor has just finished studying the mineral exhibits on the first floor and wants next to move to the dinosaurs on Level 4. If the entire museum were outfitted with beacons, it is not difficult to imagine that the system could first guide the user to a nearby elevator and instruct the user to go to the fourth floor. When the elevator door opens upstairs, the user could listen for his or her Ping! sound and continue to the dinosaurs in similar fashion.

To implement the stepping-stone functionality, we constructed a database of route sequences that could connect any starting point to any finishing point. Given a large facility, that suggests a very large number of potential routes. However, because the computer knew the starting point for any given journey (if the caller had used the Ping! system to get there), the task of selecting an appropriate route appeared to be straightforward. Also, special tools had to be developed to help the system determine the starting location of a journey if the user had traveled to the most recent destination without using the Ping! system. To do this, we ended up building a tool called "Find Yourself" that was accessible via the Settings menu. When this option was selected, the computer played that caller's Ping! sound, in sequence, from beacons all around the museum. The caller listened and then pressed the key that corresponded to the beacon number that sounded loudest; the computer was able to deduce the general area in which he or she was standing, and the list of choices for the next journey was recompiled so that destinations would be presented in order from nearest to farthest.

We were also concerned that users could find the idea of following a series of stepping stones conceptually hard to master. Some research has been carried out on this subject and has demonstrated that most blind people, even some with profound intellectual limitations, are able to follow sounds to navigate, even when routes involve a series of linked steps (Lancioni, O'Reilly, Oliva, & Bracalent, 1998). Usability testing was designed to shed additional light on the practicality of this strategy for way-finding across long distances.

One of the most important elements of the Phase 1 research revolved around perfecting the acoustical properties of the Ping! sounds that were to be issued from the audio beacons. Dr. William Wiener of Western Michigan University and Adapt Enterprises, a subcontractor for the project, is a recognized expert in audition for travelers who are blind or visually impaired. Dr. Wiener and his staff set up a preliminary experiment in which visually impaired and blindfolded participants were asked to rate potential Ping! sounds based on a number of criteria. This portion of the work focused on answering a number of related questions:

- *How many different sounds can be distinguished in a single environment?* The answer to this question would tell us how many users could simultaneously use the system without becoming confused by other users' Ping! sounds. Based on the results of early user tests, we decided to limit the catalog of Ping! sounds to nine.
- *What frequencies provide the most directional sounds?* In Dr. Wiener's earlier work, this question is addressed (Wiener & Lawson, 1997). Further investigation and testing were done to confirm that the ranges set out in Dr. Wiener's earlier research are also effective for the conditions we anticipated at NYHoS.
- *What frequencies can be used most effectively to help users estimate distance?* The Ping! system offers the advantage over some existing way-finding systems (e.g., Talking Signs[1]) that relative distances between the user and various destinations are apparent. Acoustical research was carried out to determine which sounds make for the most accurate distance guessing.
- *Which sounds are the least objectionable to other visitors?* One of the most potentially serious drawbacks of the system is that it might prove irritating to other museum visitors, especially in quiet or contemplative environments. Many people complain about the audible street crossing signals that have been installed in some cities, because of the repetitious, relentless nature of the sounds (Gallagher & Montes de Oca, 1998). This problem is largely mitigated here, because the sounds are heard only when one or more blind users is present, and then the sounds are played irregularly and only for short periods during travel to destinations. However, research and testing had to be carried out to ensure that the selected sounds are especially pleasant. The development team recognizes that accessibility features must not be viewed as in any way diminishing the experience of non-disabled persons if the system is to achieve widespread acceptance. This product should be a welcome addition to the museum, not a nuisance to be tolerated.
- *What volumes are reasonable?* Because some users might have partial hearing loss, and because ambient noise levels are unpredictable, we offered the user a volume control for the Ping! sounds. However, the range of adjustment had to be carefully studied, weighing the need to make accommodations to possible user needs

[1] Talking Signs is a trade name of the Talking Signs Company of Baton Rouge, Louisiana. The Talking Signs approach calls for users to carry an infrared receiver capable of playing short audio loops when the handheld unit is pointed at any one of a number of transmitters located in an environment. Volume does not change as the user approaches the transmitter.

FIG. 5. A blind participant in user testing exploring the museum with her cell phone in one hand and her long cane in the other.

against the potential for interfering with the enjoyment of other visitors, and adding unnecessarily to the complexity of the user interface.

EXPERIMENTAL DESIGN

User trials were carried out over two weekend days in July 2003 during normal museum hours (see Fig. 5, a photograph of a blind participant exploring the museum). In four separate sessions, we brought groups of three museum visitors who were blind or visually impaired to the museum and asked them to use the Ping! system for a period of 1 hr (for a total of 12 participants). The participants, recruited from local schools and organizations for visually impaired people, had been prequalified for the experiment through a phone survey by the project coordinator, which confirmed that each was at least 12 years old, knew how to operate a telephone, and was fluent in English. Of the 12, 7 were totally blind, and the remaining 5 had varying degrees of residual vision. The youngest participant was 15 years old and the oldest was 56. The age of onset of visual impairment ranged from birth to 30 years. One person had mild hearing loss, and one was a below-the-knee amputee. For all but one, English was their primary language, and all 12 were experienced users of touch-tone phones.

Prior to the actual 1-hr test, participants were given a basic overview of the system. They were each issued a standard cell phone (Kyocera Model 2325, Verizon Wireless, New York, NY) and were shown how to place and hang up a call. We decided to disallow participants using their own cell phones because we wanted to neutralize potential differences caused by familiarity with the equipment. Next, the participants were brought to a designated "exhibit entry" point and instructed to place a call to 888-338-PING, the system's toll-free phone number. For the next hour, the participants explored the museum, visiting exhibits and other destinations (restrooms, cafeteria, and the main information desk). Each participant was followed by one of the museum's "explainers," local college students who are typically available on the exhibit floor to offer help to visitors and to answer questions and who were trained by the project evaluator to ensure that they understood standards for ethical treatment of human subjects. Here, the explainers' job was to observe the participants' actions, offering help only when it was requested of them. At the end of the 1-hr period, each participant was interviewed by an explainer to supplement data collected on the phone about their impressions and recommendations for system modifications and improvements.

FINDINGS

Overall, the trials showed that a user-activated audio beacon system can provide way-finding information and exhibit-related interpretation under naturalistic conditions, that is, when several visually impaired users are simultaneously interacting with the system during a time when other visitors are in the museum. Equipment malfunctions occurred during the trials (as might be expected in a prototype implementation study); however, all participants were able to successfully follow their personal Ping! sounds, reach destinations they had selected, and interact with exhibit components. Malfunctions included dropped calls, which required participants to start over again, and problems related to the replenishment of the catalog of Ping! sounds, so that several times, participants were informed that no sounds were currently available for their use.

Of the nine Ping! sounds that were made available as sonic attractors, some were selected more often than others. In general, the sounds that incorporated higher pitch frequencies in a recognizable or identifiable pattern appeared to be most popular, although some of these may have benefited from their position at or near the beginning of the list. Bird calls were especially popular, perhaps because their familiarity served a mnemonic purpose.

The presence of mainstream visitors did not adversely affect users' ability to navigate successfully. Likewise, based on observation and anecdotal evidence collected by the project staff during the test, mainstream visitors were not distracted by the beacons: They appeared to associate the Ping! sounds with the ubiquitous beeps and chirps of the interactive museum exhibits. In most cases, the Ping! sounds were audible over typical levels of ambient noise, although when large groups of children were present, some difficulties were reported by users trying to listen for their sound over the din. Users did not report feeling self-conscious; one said that because the sounds were not coming from him, but rather emanated from the destination point, other visitors were not necessarily aware that he was responsible for making the sounds happen.

The system recorded the number of times Ping! sounds were activated during travel to destinations or between way-points along a "stepping-stone" route. The average number of Ping! sounds used to travel along one leg of a journey was 22, varying from a low of 7 to a high of 84. Some users triggered their Ping! sounds almost continually as they traveled. Others were much more sparing, pressing the key and then thinking a bit before moving. Overall, participants who were accustomed to traveling independently had no trouble following their Ping! sounds. This is not very surprising, because people who are blind or have low vision typically use auditory cues when moving through unfamiliar spaces, and they are experienced at deducing the direction and distance to a localized sound in the environment. Participants who were less skillful at traveling on their own had greater difficulty following their Ping! sounds. Table 1 illustrates participants' assessments of how easy or difficult they found using the system.

Of the 12 participants, 2 rated their experience with the system as *excellent,* 6 said it was *good,* 2 reported it to be *fair,* and 1 rated the experience as *poor.* No participants said that the experience was *very disappointing.*

GOALS FOR FUTURE RESEARCH

In Phase 1, we carried out preliminary acoustical research that called for a small population of human subjects to express preferences on sample attractor sounds. The results of this study were used to settle on the catalog of sounds that were then offered as choices to users in the museum trials. The next step will be to analyze the Phase 1 results and to draw more objective conclusions about the acoustical properties of sounds that proved to be most effective for navigation and least annoying to the general museum visitor population. We hope to perform a statistical evaluation of the Ping! sounds that were most often chosen by users and to develop hypotheses regarding the frequency, duration, timbre, and dynamic range of those sounds that worked best at guiding users to destinations and that required users to trigger the sound the fewest times during travel. The findings of this research will be used in refining the catalog of sounds, to develop sounds that are more effective and identifiable and even less obtrusive. Further research will examine the effectiveness of way-finding using improved Ping! sounds. Finally, the research will compare travel efficiency between individuals who travel in a museum without Ping! with those who travel with the benefits of the Ping! apparatus.

During the museum user tests, ambient noise conditions varied significantly. The museum tends to be very busy in the mornings, when numbers of school and camp groups are at the highest, and much more empty and quiet in the afternoons. Some users said that they had difficulty hearing the phone messages and the Ping! sounds when the museum was crowded, and they wished for a volume control that would allow them to adjust the volume easily. Although the system did include a control that allowed the user to boost the volume of the sounds via the Settings menu, this wasn't seen as very effective by the users. It may be better to actively monitor the level of background noise on the exhibit floor and to automatically and continuously adjust the volume levels as noise levels

TABLE 1. Participant ratings of difficulty in using the system in way-finding

Question	Easy	Both easy and difficult	Difficult
How easy or difficult did you find using the system for way-finding?	8	4	1
How easy or difficult did you find using the system for way-finding along a "stepping-stone" route?	5	5	2

change. From a technical point of view, this is a straightforward proposition; however, even with this feature, some users might still want to control sound levels to compensate for their own hearing loss, and a Settings option for adjusting the volume of the phone messages should be added to the existing one that controls loudness of the Ping! sounds themselves.

We foresee a future revenue model for Ping! in which all server activity occurs at a single central location for multiple facilities where the apparatus has been installed. The economies of scale generated by this approach will probably outweigh the extra complexity it implies; by setting up a call center with 100 or more telephone lines, we can maximize the hardware and line fees investment by balancing periods of high activity at one installation against simultaneous low usage at another. In order to achieve this arrangement, we hope to install local computers that handle only the distribution of Ping! sounds to destination-mounted beacons at each museum where the system is installed. The local computer would receive information regarding which sound to transmit to which beacon, in real time, across the Internet. There are some technical issues that must be solved before this server-client organization can be realized. In particular, it will be important to ensure that the user does not perceive a time lag between pressing the phone key to trigger a sound and hearing it in the museum space. This is challenging, because of the multiple steps and distance separating the user's action and the system's response that is implied by use of Internet transmission.

Also, in future work, we hope to refine the hardware components used in the audio beacon technology. In the existing devices, FM radio receivers are used to "hear" a DTMF code that "unlocks" them for 0.5 s, during which time the Ping! sound is played. Although this system proved to be quite effective for a small system, it has drawbacks that would become more apparent when the numbers of beacons and users increase. Now, only one signal can be broadcast at a time, so that as more users log on to the system, the odds improve that one particular user's triggering of his or her Ping! sound will be blocked by that of another.

For the reasons set out in the previous paragraph, our ambition for Phase 2 is to develop a new beacon design that relies on a wireless fidelity (Wi-Fi) based (802.11 protocol) transmission system for sending signals from the computer that generates the Ping! signals and receiving them at the beacons. In this configuration, a transmitter (with repeaters set up as necessary to blanket a large facility) would send out commands to beacons, which would each be assigned a unique IP address; this would serve the same purpose as the DTMF relay and would "unlock" appropriate beacons only for a particular travel route embarked on by a user. The Wi-Fi modem would communicate with an audio output device similar to the inexpensive MP3 players currently on the market. The player would maintain the catalog of Ping! sounds in nonvolatile Erasable Programmable Read Only Memory (EPROM); the signal delivered by the facility's Ping! server would send out an instruction, for example, that Beacon 17 is to play Ping! Sound 3. This differs from the current method, in which the Ping! sound itself is output from the computer's sound card and played over the FM transmitter, a system that causes problems when it comes to handling large numbers of users, because the sound card is effectively "tied up" during the entire 0.5 s of a transmission, thereby blocking any other requests for Ping! sounds.

In Phase 1, we incorporated Tier 1 Nuance speech recognition capability (Nuance Communications, Inc., Menlo Park, CA). Although it was possible for a user to operate the system solely by speaking into the phone (instead of pressing keys), we ran into some technical difficulties here that significantly reduced the practicality of this method of interacting with the system. We found that noises other than the user's speech could trigger events in unpredictable ways, and that even the speech coming from the phone's own earpiece seemed to interfere with the recognition engine's accuracy. In the end, we had to disable the system's "barge-in" feature, which is designed to allow the user to speak while a message is being played, thereby cutting off the remaining narration and causing the system to accept the user's utterance as a legitimate word to be recognized and responded to. So, in order to use the speech capability of the system, the user had to wait until the narrator had completely finished the instruction message before being heard. On the other hand, key presses were always responded to immediately, which proved to be more satisfying for impatient users. It is worth noting that of 11 respondents, only 1 indicated that he or she preferred using speech over pressing keys to interact with the system.

It is not yet clear how to resolve the speech recognition dilemma; either we should abandon offering this feature, or it must be significantly improved. Clearly, for some users, speech is desirable, either because of physical disabilities that preclude manipulation of the small keys on cell phones,[2] or because they have not yet learned to touch-type on a phone keypad by referencing all keys to the position of the “5” key, which normally includes a tactile marking. With further research, we may be able to refine the grammar settings that control the speech engine’s recognition accuracy and rejection thresholds for nonspoken audio interference, in which case it may be possible to incorporate speech tools more successfully than was done in Phase 1.

IMPLICATIONS FOR COLLATERAL RESEARCH DIRECTIONS

Touch Graphics Company has started a conversation with producers of mainstream museum audio guide systems to consider ways to incorporate functionality demonstrated in the Ping! concept in existing or planned museum guide products. Many institutions may be unwilling to build and maintain a dedicated system that services only a small percentage of their potential audience; therefore, we hope to work with manufacturers to develop a single product that is useful for everyone visiting the museum. This is the true spirit of Universal Design, which embodies an approach to product development that stresses usability by multiple constituencies, with varying abilities and needs. We foresee a time when a museum in the market for a handheld device to provide interpretive content to individual users could choose to build way-finding capabilities, such as those offered with Ping!, into their envisioned system. By teaming with existing providers of museum tools, we believe that we increase our chances for success at entering the general market and thereby improve the odds that effective way-finding can become an ordinary feature of many public exhibit spaces.

Although Ping! was conceived for, and was first demonstrated in, a science museum, we hope to show that this technology and approach are also suited for deployment in other settings. As the population ages, and as greater percentages of capable and mobile individuals experience normal declines in visual function and acuity, we must expect an increasing demand for products that help to ameliorate the difficulties and loss of autonomy that can be associated with blindness and low vision. In recognition of this demographic shift, Touch Graphics is beginning to consider ways that networked audio beacons could contribute to improvements in way-finding in nonmuseum contexts. For example, an independent living center for seniors could be outfitted with Ping!; users could navigate from their living quarters down corridors to elevators, from where they could access each floor and the facilities available there. We could even extend the idea of using cell phones for way-finding to include other “remote control” operations such as unlocking doors, indicating floor requests in the elevator, and an endless range of other tasks that usually require finding and mastering unfamiliar equipment and controls. The phone has the advantage of offering context-sensitive spoken help and instructions; it is familiar and comfortable, and if usage charges are reduced to the point that one flat rate covers unlimited minutes, there may soon be no financial incentive to restrain ourselves from using it with the freedom with which we currently consult our wristwatches.

In recognition of the extensibility of the Ping! concept, we hope to experiment in Phase 2 with some non–museum-centered applications. This will include informal installations of phone-based way-finding and control systems in a variety of settings. Although these have not yet been determined, some possibilities include

- mounting beacons on pedestrian-activated crossing signals, so that users can easily find the button that changes the traffic light;
- installing beacons on the exterior of buses, next to the passenger door, so that a user can determine which bus is the one he or she is waiting for and then board it independently; and
- placing beacons inside a facility, such as the Heiskell Library for the Blind and Physically Handicapped in New York City, to facilitate users’ moving through the space, locating stacks, and finding the materials they are in search of.

CONCLUSION

Cell phone use is growing explosively: “In 1994, 16 million Americans subscribed to cellular phone services. Today, more than 110 million Americans are subscribers. Some experts predict that worldwide subscribership will reach 1.2 billion people by 2005” (Gaudin, 2001). As technology and market penetration improve, cell phones will become cheaper and more reliable.[3] Historic patterns of technological convergence suggest that a single data appliance will survive and others will wane,

[2] Some blind individuals have conditions that are accompanied by reduced fingertip sensitivity, which may make operating keys on a cell phone difficult or impossible.

[3] Cingular Wireless is already offering a promotional “24/7” plan that charges a single rate regardless of usage. Presumably, other companies will follow.

and the cell phone appears to be emerging as the single indispensable personal tool for the 21st century. Communications products that leverage growing cell phone popularity will be more likely to achieve widespread acceptance than those that rely on less universal platforms. Furthermore, cell phones are ubiquitous, cheap, and familiar, and because they rely on an audio and tactile interface, they are an ideal tool for individuals who do not rely on vision as their primary means of acquiring information about the world.

The project that is the subject of this article tested a new strategy that takes advantage of these developments as a way of promoting better accessibility to public exhibit spaces for people who are blind or visually impaired. We demonstrated that an effective way-finding and content delivery system could be built on to the existing wireless phone network. Other researchers are investigating the use of new location-aware computer devices to provide access to text-based information about the outside environment (May, 2003). Our team has chosen, instead, to rely on a simpler, more intuitive approach that takes advantage of users' existing skills at traveling through new environments and that does not require them to carry and learn expensive and unfamiliar hardware devices.

UPDATE

Since this article was prepared, the research team has been awarded a Phase 2 SBIR grant from the National Science Foundation (contract No. DMI-0432973) for carrying out additional research on the Ping! concept. Ongoing work will result in the installation and testing of a more advanced system in the New York Hall of Science in 2004 and 2005.

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