Wayfinding Technology: A Road Map to the Future

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Abstract: From a broad visionary perspective, this article examines three promising areas in which technology has the potential to revolutionize wayfinding for travelers who are blind: smart environments, smart consumers, and smart helpers. Its perspective is personal, based on the author's experience as the director of the Institute for Innovative Blind Navigation, and it is strongly influenced by the research and writings of popular futurists.

The profession of orientation and mobility (O&M) has an extensive research base that provides a foundation for using a variety of technologies to improve the travel skills of individuals who are visually impaired (that is, those who are blind or have low vision) (Blasch, Wiener, & Welsh, 1997; Jacobson, 1993; LaGrow & Weessies, 1994). In this literature, the term *wayfinding* is defined broadly as a process for navigating through environments and traveling to locations along relatively direct paths (Long & Hill, 1997). Historically, the long cane and the dog guide have been the wayfinding tools of choice for O&M instructors. As new wayfinding technologies emerge, however, the cane and dog guide are becoming part of a larger collection of potential tools for addressing the navigational needs of persons with visual impairments. The choice of tools will be determined by the needs and desires of individual consumers, often with the guidance of O&M instructors.

Wayfinding technologies are likely to evolve rapidly as computer processing chips with communications capabilities become embedded in the environment, in the tools for probing and sensing space, and in robots. As computer chips shrink in size, they become less expensive to manufacture and, therefore, will be more likely to be embedded easily in the fabric of the world.

Computer chips can already be found embedded inside "smart" fabrics, "smart" clothing, and "smart" accessories (Gershenfeld, 1999). These chips allow, for example, people with health problems to monitor and report their medical conditions continually; military personnel, police officers, and firefighters to carry embedded specialized tools, identification codes, and communication systems; and sports enthusiasts to register vital signs for physical conditioning. They can be increasingly found in signage, enabling signs to talk and store information. They can be placed on surfaces, walls, floors, ceilings, desktops, poles, sidewalks, and roads (Rheingold, 2002). Embedded chips are creating "smart" spaces (spaces that contain embedded computer chips, often with sensing and communications capability), resulting in advancements, such as actuated intersections and intelligent highways. Such innovations make intersections and highways safer, improve the flow of traffic, save money, and embed intelligence in spaces with the potential to assist visually impaired individuals as they travel. The tiny chips are even being surgically implanted in living beings (as in heart pacemakers), making bodies the carriers of embedded intelligence. The future will be strongly influenced by the evolution and implantation of these tiny computer processing systems. As this revolution unfolds, technologies will have the potential to improve wayfinding for persons with visual impairments.

Technology is increasing exponentially (Kurzweil, 2001, 2003; Moore, 1965). Two futurists, Gordon Moore and Raymond Kurzweil, both of whom developed "technology laws," identified this incredible rate of change. Moore (1965) stated that every 12 to 18 months, scientists would produce computer chips that were twice as capable as the previous generation. Each new generation of computer chips would be twice as fast and store twice as much information, yet cost the same or less than previous chips. Kurzweil (2003) predicted that after we reach the physical limits for making computer chips, we will discover new technologies that will continue to double the processing power. He further predicted that the next breakthrough in computing power would be three-dimensional molecular computing.

Given the incredible and predictable rate of growth in technology, this is a time when it is no longer necessary to wait for technologies to arrive. It is becoming increasingly possible to create the futures that can be envisioned. The task involves envisioning a high-technology (hereafter "high-tech") future and then figuring out how the technologies can be used together to make the best possible outcome for wayfinding.

Given Moore's and Kurzweil's laws, it follows that about every 18 months, a new set of technological innovations will emerge with the potential to improve wayfinding tools. This scenario has been shown in the steady evolution of near-point tools for persons who are blind, such as refreshable braille, braille computers, and talking screen readers. Only recently, though, has technology evolved with enough computational power to create wayfinding tools.

Smart environments and the need for environmental literacy

Buildings and pathways were historically created to accommodate the sense of vision. The environment was filled with lines, symbols, and nontalking signs to provide information for sighted people. It was not constructed to tell people with visual impairments what to do (Kish, 1995). The potential of smart spaces has changed this situation. The environment could be constructed to improve wayfinding by placing custom chips in the spaces that need modification. For example, at street intersections, smart wayfinding chips could be designed to *sense* the presence of a traveler with a visual impairment, *decide* what information to transmit, and *communicate* this information. A network of wayfinding chips could provide access to location-based information through global positioning satellite (GPS) technology, activate talking signs, and connect to the Internet. The chips could be embedded anywhere they seem to be needed, such as in street signs, in store logos, on address numbers, on buildings, on floor surfaces, and on directional arrows.

Some spaces need little management, while others are more problematic and require more management. Familiar areas, like the inside of a person's house or a familiar workspace, do not necessarily need intervention because navigation is usually simple and safe. Other areas, however, like open spaces (for example, parks, playgrounds, parking lots, and gas stations), street intersections, and complex indoor spaces (for example, airports and malls), as well as the inside of vehicles (where there is no feedback about what is being passed or about the vehicles' positions in the geography), are more difficult for individuals with visual impairments to negotiate. Such areas, therefore, require greater spatial management.

Location-based technologies are helping to create smart spaces. Location-based knowledge has two components: a usually wireless system for labeling longitude and latitude and managed geographic databases, some of which are filled with details of maps and landmarks. The result of these technologies is that every spot on earth has the potential to get progressively smarter and to gain more knowledge about itself. This knowledge will get richer as institutions continually add details to the geographic databases. The institutions that are assembling databases about locations have spawned a new industry to provide consumers with location-based services that will be used by environmentally literate persons. Environmental literacy is the ability to use the technologies to gather knowledge about spatial location and the services associated with these locations. It may turn out to be as important as academic literacy.

The term *environmental literacy* draws attention to accessibility rights. It is well accepted in the culture of North America that people with visual impairments have the right to be literate. There is a legal mandate to modify all types of media (for example, video, the Internet, television, print) so that visually impaired individuals can gain access to the culture's knowledge base. Technologies that assist with these mandates are often paid for by governmental programs, and research and development is encouraged and financially supported. A similar set of legal and cultural mandates may need to evolve to support the development of environmental literacy.

The blindness community will not have to restructure the environment to take advantage of smart spaces, since the sighted world is rapidly mixing intelligence into literally everything, including buildings and pathways. At IBM's Almaden Research Laboratory, scientists have developed an idea called WorldBoard, an ambitious effort to make the entire planet into a geospatial bulletin board. WorldBoard is described as follows:

> What if we could put information in places? . . . what if we could associate information with a place and perceive the information as if it were really there? WorldBoard is a vision of doing just that on a planetary scale and as a natural part of everyday life. For example, imagine being able to enter an airport and see a virtual red carpet leading you right to your gate, look at the ground and see property lines or underground cables, walk along a nature trail and see virtual signs near plants and rocks. (Spohrer, 1999, p. 602)

If the red carpet leading to the airport gate had the ability to communicate and if this virtual signage had the ability to talk and to transmit its knowledge to receivers, then valuable information would be available to assist in wayfinding. This is a component of environmental literacy that must be accessible to individuals who are visually impaired.

Communications systems that have the ability to talk will be built into technologies for persons who are sighted because it is inexpensive to include this feature and sophisticated consumers are always on the go. People on the move require messages to be read to them while they are completing other tasks. So, the blindness community will not have to create its own technologies but, rather, will choose and assemble systems with speech capability from available technologies in the mass market. Adaptations will always be necessary, but mainstream industries will provide the basic technologies for talking communications units.

If environments contain embedded knowledge and have the ability to communicate, then there has to be a system carried by a visually impaired person that gathers the embedded information and makes it accessible. The sighted world is moving rapidly toward the concept of wearable computing devices, which will embed invisible chips into the fabric of clothing and accessories. For persons with visual impairments, wearable systems may have to be modified to create a special processing system. Such a "blind wayfinding suit" may not have to be created or invented; it may be assembled from available technologies.

Smart consumers: The age of the cyborg

Not only are environments getting smarter, but so, too, are the tools that consumers use to probe the world around them. These tools are held in the hand, worn in headgear, or incorporated on (or into) the human body in some way. When computer processing intelligence is embedded in these tools, they become part of the wearable computing revolution.

This is the age of the cyborg (Mann & Neidzviechi, 2001). A cyborg is a human being who incorporates technology on or in the body. This definition makes almost everyone on the planet a cyborg. Contact lenses, eyeglasses, hearing aids, heart pacemakers, insulin pumps, and other devices make human beings into cyborgs. What makes this the age of the cyborg is the acceleration in the varieties and complexities of the intelligent technologies that are now being embedded on and in the human body. The bionic people who were the 20th century's science fiction are this century's reality, making this the age of smart consumers.

Each generation is comfortable with the cyborgs of their culture. People who wear contact lenses today, for example, are not considered out of the ordinary. At the same time, every generation is also cautious about or rejects the new cyborgs of the emerging generation. The horse-and-buggy generation did not feel at home with the motorized world of the emerging generation. The generation that is completely at home jogging in Nike shoes is uncomfortable with the idea of electronic clothing. The next generation of cyborg development will not go away, nor will the fast pace of change slow. The questions that the field of visual impairment will face are, What kind of cyborg will enable seamless wayfinding? and What kind of modules should be attached to the body that will enhance wayfinding? Some parts of the answer to these questions are already understood.

Existing wayfinding technologies, such as Kaspa, the Sonic Pathfinder, and the vOICe, are really varieties of wearable computers. They require head mounts for cameras, ultrasonics, and computer units. Electronics that make up handheld units, such as the Miniguide and Sound Flash, could be made into wearable modular elements of a larger, wearable wayfinding suit. Location-based technologies require computer processors. GPS receivers and communications modules that must be carried or worn are thus a subcategory of wearable computing devices. Talking signs must be activated and speech access must be provided for such technologies to be beneficial for persons with visual impairments.

One of the most powerful capabilities of computer chips is that they can be networked to communicate with and influence each other independently of any human intervention. So smart chips in cars could be designed to communicate with smart spaces, such as intersections. Smart consumers, wearing embedded computers, could communicate with smart cars and smart intersections. Internal chips, embedded inside the body, could be networked with wearable systems or with smart environments. A wayfinding suit could network with the smart environment, including smart traffic lights, smart ped-heads (pedestrian signaling units, often with audible feedback), smart signs, smart vehicles, smart pathways, and smart classrooms. Over time, all the components of these technologies will become smaller, less expensive, and smarter.

As computer processing systems become increasingly embedded in the eyes and eventually throughout the brain in vision-processing networks, the blindness community will be faced with new challenges. These approaches will provide new kinds of perception that have not yet been seen in rehabilitation (Geary, 2002). People with artificial vision systems will see in ways that human beings have never experienced. These new systems may provide enhanced digital senses that not only compensate for losses, but offer new and more powerful bionic senses.

Computer chips that are embedded into sensors have caused another kind of revolution that directly affects wayfinding technologies. Tools that see, hear, feel, and smell are being combined with microprocessors. Thus, tools like computer vision systems, face-recognition technology, cameras, listening devices, artificial noses, and skinlike surfaces are all following Moore's law: getting smarter, cheaper, and smaller every 18 months. They are causing a robotics revolution, making any object into a surveillance tool or into a system that augments human perception. These new "smart things with senses" can be designed as "smart helpers" for people with visual impairments.

Smart helpers: The coming of the robots

Standing inside smart environments and alongside smart consumers is a unique collection of emerging robotic creatures that may be called "smart helpers." These robotic creatures can become wayfinding toys for children with visual impairments, helping companions for adults who have travel disabilities, and smart vehicles. Any object that contains intelligence, sensory systems, and the ability to communicate can become a smart helper, but the systems that can move independently about the environment constitute a special class of technology with the potential to be wayfinding tools.

GPS modules, for example, can be placed in vehicles, embedded in features of the environment, included as part of wearable computing suits, or be incorporated as add-ons to robots. Additional modules can be added. A list of potential wayfinding modules may include units for recognizing faces and patterns, enhancing and filtering the senses (for example, removing ambient noise and enhancing helpful sounds, increasing contrast in one area, and decreasing glare), navigational systems with the ability to detect and avoid obstacles, memory units that record images and sounds, communications networks (cell phones, e-mail systems, video conferencing), speech-recognition systems, expressive speech units, and so forth. Following Moore's law, for example, such modules will get smaller, cheaper, and more powerful every one to two years and can be replaced when upgraded modules become available.

Applying this understanding to digital toys results in ever-smarter robots for children. Giving dolls and toy animals lifelike qualities is the future. Sony's robotic dog, AIBO (Dawson, 2001), is an example of a toy that could be modified to serve the needs of blind children. It could theoretically be programmed and equipped with any of the specialized processing modules just mentioned. AIBO could be equipped, for example, with modules that encourage play activities that are designed to further the developmental progress of visually impaired children. It could play hide-and-seek to encourage the development of sound localization and movement toward landmarks. AIBO could sing songs, teach travel routes through a house, warn about steps or stoves, read books, or use wayfinding language (for example, *landmark, masking sound, left,* or *right*).

The most recent generation of AIBO can walk, run, chase a ball, wag its tail, respond to 75 voice commands, read Internet messages, express emotions, display instincts (for example, play, search, hunger, sleep), "see" in real time, take pictures through a hidden nose camera and store them, recognize its own name and its owner's name, plug itself to recharge, and respond to other AIBOs (Dawson, 2001). This robotic dog has built-in infrared distance receptors and sensors for temperature, vibration, and acceleration. Sony is aware of the potential use of AIBOs as a tool for individuals with visual impairments, but cautions that the technology is not yet powerful enough to be used as a fully-developed guide system for wayfinding. As a toy for children with visual impairments, however, AIBO has capabilities that can be exploited now.

Many O&M instructors and travel trainers work with navigationally impaired individuals (that is, those who have visual anomalies that fall outside the standard definition of visual impairment or those with typical vision whose navigational centers in the brain have been damaged). These individuals often have severe cognitive, multisensory, or physical impairments. Autistic children, for example, sometimes relate better to machines than to people and have vision anomalies, such as the failure to recognize faces, that fall outside the standard definition of visual impairment. This population may benefit from robotics in ways that are not relevant to visual impairment, but that may nevertheless fall within the professional responsibilities of O&M instructors.

Although current robots are not ready to be wayfinding assistants for sophisticated travelers who are visually impaired, they may be ready for use with people who have navigational disabilities. Honda's ASIMO humanoid robot (an acronym for Advanced Step in Innovation Mobility) can already turn lights off and on, walk up and down steps, and navigate through indoor spaces (Honda Motor Company, 2003). One can envision a robot helper bringing in the newspaper, pouring coffee, pushing a wheelchair, and vacuuming a rug. ASIMO costs about as much as a sophisticated wheelchair.

In addition to advances in robotics, automobiles are becoming more autonomous and are starting to see, sense, run self-diagnostics, use collision-avoidance systems, and gain access to location-based services. Two avenues in which automotive technology could be applied to other vehicles with a potential to improve wayfinding include traveling with wheelchairs and small scooters. Wheelchairs have become more sophisticated. Modern power carts are stable, have long-lasting batteries, and can be equipped with control switches to allow navigation using head movements, blow switches, or eye movements. There is no reason why the standard modules listed earlier could not be incorporated into smart wheelchairs that would be especially designed for people with visual impairments. GPS-equipped cars are becoming standard, and GPS-equipped wheelchairs could be, too. Wheelchairs can be equipped with signage activators, obstacle detectors, radar warning systems, and so on, in effect creating "blindness-specific" power vehicles. The same modules and strategies can be used to manufacture small scooters, bikes, and toy cars.

Convergence: The blending of technologies

The long cane is a low-technology (hereafter "low-tech") solution to wayfinding that will not disappear as new tools emerge. High-tech changes will not do away with low-tech solutions that work. The pencil and the ink pen have not been supplanted by the word processor, nor has radio disappeared with the advent of television. Similarly, braille did not disappear when talking machines were invented. Low-tech devices survive the arrival of more sophisticated tools and, in doing so, become part of a growing army of tools to help people.

In addition, low-tech options tend to merge with high-tech options. For O&M instructors, this fact means that the cane has the potential to take on more and more intelligence over time. The Batcane, developed by Cambridge Consultants (2003), which uses ultrasonic echoes and tactile feedback, is an example of this merging of high tech with low tech. Dog guides have been carrying embedded chips for several years. In the future, dogs or canes could carry GPS units, obstacle detectors, or chip systems that interact with smart intersections.

The cell phone is blending with various technologies, including GPS systems, web and e-mail access, face-recognition digital cameras, walkie-talkies, palm computing, and environmental activation. It is becoming a remote device for turning systems in the environment on and off. As technology moves forward, all the components will become smaller and less expensive, so the cell phone will become part of wearable processing systems. Modifications in this evolving set of technologies can and eventually will be adapted for wayfinding.

Perspective of the Institute for Innovative Blind Navigation

In summer 2001, the Institute for Innovative Blind Navigation (IIBN) received funding from NEC Foundation of America to bring issues of advanced wayfinding technologies to the blindness community. IIBN's goal was to accelerate and intensify the debate about these new high-tech tools.

Since then, IIBN has offered regional wayfinding seminars to introduce the issues to professionals and consumers. An outline for understanding and discussing emerging navigational technologies evolved from these seminars, as did the set of recommendations presented next. These recommendations are global issues that offer guidelines for future discussion and consideration. Additional information can be found on IIBN's web site, www.wayfinding.net.

Recommendation 1: Train more specialists. New kinds of specialists need to be trained to deal with environmental literacy, wearable computers, and robotics. Technology eliminates more jobs than it creates (Rifkin, 1995). For O&M, the implication is that the low-tech job of teaching cane skills or sighted guide techniques may dwindle, while jobs that require a high degree of mastery over sophisticated wayfinding technologies are likely to increase.

Recommendation 2: Build or repair the infrastructure; create new institutions or restructure traditional institutions. Revolutionary technologies undermine old institutional structures and require that new institutions be created that can change rapidly, embrace the new assistive technologies, specialize in particular wayfinding tools, study and help develop the emerging technologies, and train consumers and professionals. In the field of the rehabilitation of persons with visual impairments, new kinds of institutions should be created or existing ones restructured. This is an opportunity for new programs to develop in the universities; for new research-and-development laboratories to be created; for inventors to create and market new tools; and for established leaders in the field to reinvent themselves, their disciplines, and their organizations.

Recommendation 3: Form partnerships. Institutions, like individuals, may have difficulty coping with the flood of new technologies. Widespread cooperation among institutions and individuals will be needed to embrace the constantly evolving technologies. Significant changes in technology require significant changes in thought, which, in turn, require significant changes in responsibility and focus. The potential of technology is an excellent platform on which to begin a new age of cooperation. Consumer groups can play an important role in the development of technology for wayfinding. The National Federation of the Blind, American Council of the Blind, and blind veterans' groups can and should lead the way as technology moves forward.

Recommendation 4: Create a global strategy to address continual advances in wayfinding technologies. The blindness community should come together to hold an extended dialogue about the implications of accelerating technology. Focus groups and action strategies should be established that address the totality of the challenge. Also, biennial international conferences should be created solely to address advances in wayfinding technology. Furthermore, technology training camps should be created to establish a national infrastructure for teaching the use of wayfinding technologies as an intermediate solution while existing institutions adjust to the digital age.

Recommendation 5: Think process and platforms, not products. Technology products are headed for obsolescence in 18 months or less. Whatever is created must be understood to be part of a long-range plan, with built-in upgrades coming every one to two years. We must think in terms of "technology platforms" in the process of continual evolution. A service model, rather than a business model, may be a better way to address this challenge. A service model sells memberships in a technology platform, and members ride the wave of progress. A business model sells products that quickly become obsolete. In a service model, O&M instructors would sign on with an organization and pay membership fees to obtain, for example, lifelong education and training, location-based services (GPS units and database linkage), technical support, upgrades, and new technologies at reduced cost.

Recommendation 6: Custom design technologies to the individual. It is now possible to analyze and prescribe technology that is specific to individual needs. The steady rise in computing power, as well as the decrease in prices for the components of any tool, makes it possible to do so. The field of O&M may need to consider using a medical model that includes a set of diagnostic strategies, combined with a collection of technology modules that could be assembled to address the wayfinding needs of clients.

This is a challenging, but hopeful time. Great things can happen if those in the blindness community—consumers, professionals, families, and support agencies—work together to mold emerging technologies into practical and inexpensive wayfinding tools.

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