AUDITORY ASSISTIVE DEVICES FOR THE BLIND

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ABSTRACT

Most auditory assistive devices for the Blind employ synthetic speech. These include talking computer interfaces, reading machines, talking signs, and a plethora of talking appliances and gadgets. Some devices use warning tones to signal events or localize objects. Sonification in assistive devices is limited to wayfinding systems that encode range into frequency. There are now some prototype systems that offer more complex sonifications for wayfinding and interpreting images. There still are no assistive devices that use both 3D sound and sonification to augment the auditory environment.

1. INTRODUCTION

Approximately one million people in the United States are considered "legally blind."[1] For the purpose of defining eligibility for blindness-related disability benefits, a person is blind if the smallest detail that can be resolved visually in the better eye with refractive errors corrected is 10 minutes of arc or greater, or the horizontal extent of the visual field with both eyes open is less than or equal to 20 degrees.[2] About 10% of the people who are classified as legally blind have no useful vision – they are totally blind.[3] With impairment or failure of vision, blind people must shift their attention to other senses to obtain information about the environment. Those who are totally blind depend entirely on hearing, touch, smell, and the vestibular sense to perceive, interact with, and move about their environs.

After vision, hearing has the broadest band for acquiring information. Blind people rely almost entirely on hearing to perceive the environment beyond their reach. A highly skilled blind pedestrian can approach an intersection, listen to the traffic, and on the basis of auditory information alone, judge the number and spatial layout of intersecting streets, the width of the street, the number of lanes of traffic in each direction, the presence of pedestrian islands or medians, whether or not the intersection is signalized, the nature of the signalization, if there are turning vehicles, and the location of the street crossing destination.[4-5] Of course, not all blind people demonstrate these skills,[6] but enough do to reinforce the prevailing belief that blind people have supernormal auditory perception capabilities.

The idea that blindness leads to a perceptual compensation that is manifested as an over-performance of hearing has found support in cortical electrophysiology,[7-8] functional brain imaging,[9-10] and behavioral studies.[11-12] Large amplitude auditory evoked potentials can be recorded over the occipital cortex in blind people;[8] blood flow to the occipital visual cortex increases with auditory stimulation in blind people;[9] and lateral sound localization is more precise for blind than sighted people,[11] ferrets,[13] and cats.[14] However, contrary to the perceptual compensation hypothesis and the conclusions of other studies, a recent investigation finds no difference in sound localization performance between blind and sighted subjects along the azimuth,[15] and poorer performance for blind subjects for sounds differing in elevation.[16]

Undoubtedly learning plays an important role in auditory scene analysis and perhaps sound localization performance. Obviously blind people have more experience attending to and interpreting environmental auditory information than do blindfolded sighted people, the usual comparison group. Serving the needs of the Blind is a natural application of the knowledge and technology that falls under the rubric of sonification. Auditory displays can aid blind people with orientation and mobility, using GUIs, visualize information, and perform daily activities. The present paper briefly reviews existing auditory assistive devices for the Blind and identifies new research opportunities on the perception of auditory environments that could benefit the Blind.

2. DEVICES THAT TALK

The most common use of sound in assistive devices for the Blind is in the form of synthetic speech. There is a plethora of devices that display information by talking to the user. Computer-users and web-browsers can use screen-reading software to listen to textual information that appears on the computer monitor. Leading examples are JAWS,[17] Hal,[18] Window-Eyes,[19] Simply Talker,[20] VIRGO,[21] and WinVision.[22] The main limitations of screen readers are difficulty navigating GUIs and highly graphic webpages. Also, many websites and software displays are not screen reader accessible, or they are poorly designed for accessibility.[23] An area where the novel uses of sound should be explored more fully is to supplement screen readers with navigation aids that will assist blind computer users navigate web pages and use application software that depends on GUIs.

Other devices that read text include reading machines, Newsline®, and Talking Books. Reading machines consist of a document scanner, OCR software, and a speech synthesizer. The first reading machine for the Blind was invented by Ray Kurzweil in the early 1970s and introduced in 1976. That invention earned Kursweil the National Medal of Technology from President Clinton in 2000, the Lemelson-MIT prize in 2001, and induction into the National Inventors Hall of Fame in 2002. Current versions of reading machines include the VERA,[24] Ovation,[25] , Galileo,[26] and of course the Kurzweil 1000.[27] Reading machines are now mature technology and have become very reliable and affordable.[28] However, this 30-year old technology has limitations. Reading machines make text that is printed on flat paper accessible to the Blind, but locating print in the environment and reading it is still an unsolved problem. Again, clever uses of sound can be envisioned that will aid the Blind in localizing and reading signs, scanning the environment for printed documents, and browsing through printed material to find something of interest.

The National Federation of the Blind's Newsline® provides access to dozens of major daily newspapers on the morning of their publication through synthesized speech over the telephone.[29] A major innovation of Newsline® are the sophisticated browsing and search features. Using a touch-tone phone, blind readers can select sections of interest, choose articles to read, skip material, repeat passages, and search on keywords.

The National Library Service for the Blind and Physically Handicapped (NLS), a division of the Library of Congress, offers free loan of audio books (Talking Books) and magazines for the Blind.[30] The material is recorded by sighted readers and is produced as cassette tapes and audio discs (vinyl records) in a non-standard format. Special tape and disc players, provided by the NLS free of charge to eligible participants, are required to play back the recorded material. The NLS currently has an inventory of over 23 million copies of Talking Books and recorded magazines and 730,000 playback machines. This older analog technology does not provide the sophisticated browsing and search features of the all digital Newsline®. However, the NLS is currently in the early stages of a long-term digital conversion project.

A variety of talking gadgets and appliances has been available for many years.[31] Examples include talking watches, clocks, timers, calendars, thermometers, thermostats, scales, glucose meters, blood pressure meters, tape measures, prescription medicine bottles, pill organizers, calculators, compasses, money identifiers, microwave ovens, automated teller machines, ticket machines, and personal organizers. The Can-Do Recorder enables people to record messages on cards with magnetic strips that then can be attached to various objects.[32]

One of the most sophisticated talking gadgets is The Braille 'N Speak[33] and its companion, Type 'N Speak.[34] These two devices are talking personal digital assistants used primarily for note-taking that are custom-designed for the Blind.

Anything that has a display can be, and most likely has been, equipped with voice output. Talking gadgets are products that are normally equipped with displays, but made accessible to the Blind with synthetic or recorded speech. The disadvantage of talking gadgets is that they share their information with anyone within hearing range.

Synthetic speech is so ubiquitous that it has become the obvious solution to many challenges faced by the Blind. The most recent example is a GPS-based wayfinding system designed for the Blind that provides a steady narrative on instantaneous location, travel directions, and points of interest.[35] This system, developed by Mike May and his colleagues in the Sendero Group, combines digital talking maps with a GPS unit. Digital talking maps, such as Atlas,[36] have been available for several years. Other talking wayfinding aids include talking information kiosks and talking signs.

Talking Signs® is an infrared communication system that consists of an emitter that is permanently installed in the environment and a hand-held receiver.[37] Upon activation by a receiver, the emitter sends a recorded voice message that is played on the receiver. In principle, emitters could be installed anywhere there is a sign or signal conveying information important to blind pedestrians. The emitted signal is directional so that it also can be used for homing. This feature is particularly valuable when crossing the street where the emitter is mounted on the ped head.

Talking devices are to sonification what reading is to visual information processing. A well equipped blind person could have a chorus of synthetic voices providing up-to-the-minute details on everything of potential importance. Descriptive audio is now available to the Blind who wish to follow television programs,[38] movies,[39] and live performances.[40] One could easily imagine a future extrapolation of such technology, combined with intelligent machine vision and synthetic speech, that would provide the blind person with a continuous narrative description of the objects and events in his or her environment. It is unlikely that such technology would be whole-heartedly embraced by the blind community. Not all information is optimally conveyed with a verbal description. However, as illustrated by the street crossing example in the introduction, the intelligent use of sound has the potential of creating a rich dynamic image of the environment.

3. DEVICES THAT SIGNAL

A wide range of assistive devices use audible signals to aid the Blind. Some are as simple as the "Boil Alert" which is a glass ring that rattles against the sides of the pot when the water boils,[41] or the familiar whistling teakettle. Other signaling gadgets include the EZ Fill liquid level indicator, which sounds an alarm when the liquid in a glass or cup reaches a specified level,[42] and the Count-A-Dose syringe loading system,[43] which produces a click for each unit of insulin drawn into the syringe. More sophisticated signaling systems include floor indicator bells in elevators, beep balls, and audible pedestrian signals.

An interesting and challenging application of signaling for the Blind is beep baseball.[44] Beep baseball is played with a 16 inch softball equipped with electronic circuit boards, batteries, and speakers that emit a constant beeping. A sighted pitcher pitches the ball to the blind batter. If the ball is hit more than 40 feet, it is fair and the batter runs the 100-foot distance to one of two bases. The bases are padded cones that also are equipped with electronics and speakers. When the ball is hit, one of the two bases, chosen at random, begins to buzz. The batter must reach the buzzing base before one of six blind fielders obtains possession of the beep-ball. Sighted coaches on the sides of the field call out numbers to the fielders when the ball is hit to activate coordinated plays. All players, except the sighted pitcher and catcher, must wear blindfolds. The game, which taxes sound localization skills, is very popular and highly competitive.

Audible pedestrian signals are becoming familiar features in the urban auditory environment. The Millennium Edition of the Manual on Uniform Traffic Control Devices prescribes standards for accessible pedestrian signals.[45] A clicking locator tone (e.g., 880 Hz square wave) repeats at a low frequency (e.g., 1 Hz) to guide the blind pedestrian to the signal activation button. A cuckoo sound (e.g., 800 Hz and 1200 Hz presented every 1.5 sec) signals that it is safe to cross the street in one direction (usually the north-south crosswalk) and a chirping sound (e.g., 2000 Hz presented at 1Hz repetition rate) signals that it is safe to cross the street in the orthogonal direction (usually the east-west crosswalk). Many of the manufacturers include automatic volume controls to keep the signal sound just above the ambient noise level in order to reduce noise pollution. The disadvantages of the accessible pedestrian signals are that mockingbirds and cat birds have been known to mime the cuckoo and chirp signals and in some environments the crossing signals can be difficult to localize.

Signaling systems are the simplest form of sonification. They add auditory objects to the environment that convey information about the environment. The signaled information is typically binary, but the sound source itself, such as the locator signal for crosswalk controls, provides much richer auditory information that identifies its location in the environment. A useful principle demonstrated by many signaling devices for the blind is that auditory objects can serve as fundamental building blocks of auditory environments.

4. DEVICES THAT SONIFY

"Sonification is the use of non-speech audio to convey information."[46] As reviewed above, most assistive technology for the Blind employs speech. Auditory localization of the sound source tells us the object's location and provides information about the object's relative motion. But, to understand object attributes, we must convey that information in the attributes of the sound. A few innovative assistive devices for the Blind can be classified as devices that sonify by encoding information in sound parameters.

Both the Miniguide[47] and the Sonic Pathfinder[48] use sonar systems to detect objects while walking. The user's distance from the object is computed from the echo and displayed to the user as a tone of varying pitch. As the user approaches the object, the pitch of the signal tone goes up (approximately 30cm/tonal step for the sonic guide and 20cm/tonal step for the Miniguide).

The KASPA[49] is a more complex sonification system for the Blind. Based on technology developed in the early 1960s by Leslie Kay,[50] the KASPA consists of a sweep FM ultrasound emitter and three laterally displaced sensors. The signal received from the echo is beat against the outgoing signal to produce audible sounds. The frequency of the sound is inversely proportional to the range and the timbre carries information about reflection properties of the object. The user must learn to interpret the sounds, a process that can take several weeks of experience. The multiple features make it possible for the user to localize objects with binaural cues.

The vOICe, developed by Peter Meijer, a Dutch physicist at the Philips Research Laboratory in Eindhoven, is a sonic imaging system for the Blind.[51] Digitized images are sonified by transforming the x-coordinate of the image to time, the y-coordinate to frequency, and grayscale to loudness. The system operates as if a vertical line scanner is swept horizontally across an image at a constant rate. The sound's pitch varies with the position of the pixel on the vertical axis and the loudness varies in steps with steps in the pixel's gray level. The result is a complex dynamic sound with chords and melodies as the scanner sweeps across the image. Needless to say, this system takes a long time to learn. It has been described as equivalent to learning a foreign language. However, some blind users offer encouraging testimonials.

5. CONCLUSIONS

Most auditory assistive devices for the Blind employ synthetic or recorded speech. A few devices use a primitive and abstract form of sonification. This creates a heavy learning burden on the blind user.

Both sighted and blind people are able to interpret the cacophony of sounds around them as an auditory image of the environment. This everyday perception of the world is a natural and intuitive example of sonification. An important question is "How do blind people visualize their environment when relying only on auditory information?" A suitable answer to this question could lead us to the development of technology that can sonify information by transforming it to represent an auditory environment.

Much of the emphasis in using sonification to aid the Blind has been placed on encoding environmental information in frequency, timbre, loudness, etc. of the sound. An alternative strategy would be build an environment from auditory objects that have distinguishing sound attributes and can be localized in space. The auditory objects could move and spatial patterns could be constructed from the pattern of movements of the auditory objects. The Blind often talk of using "auditory flow fields" to navigate and interpret the environment. The properties of auditory flow fields and their effects on the perception of the environment must be understood in greater depth.

Research on understanding auditory perception and the application of sonification principles for assisting the Blind is in its infancy. Many of the early attempts at using sonification, even in its simplist form, have not been adopted by the Blind. Rather than build elegant, but complex instruments that require extensive learning to master the codes before they can aid the Blind, we must focus on how the Blind now perceive their world through sound. Then we can design technology that takes full advantage of the powerful auditory information processing capabilities of the Blind.

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