Assistive Devices for the Visually Impaired for Ground-Level Object and Surface Condition Detection

Literature Review

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Abstract

This literature review focusses on identifying the reasons for the need of improved ETAs (Electronic Travel Aids) for individuals with visual impairments. Through analyzing flaws in current devices and identifying common feedback for new technologies, common issues can be identified. These can be categorized into design, learnability, and capability flaws. The flaws are not only identified, but reasoning and evidence is given to explain their causes. Awareness of these flaws and their causes can help to answer the question of how assistive devices for individuals with visual impairments should be improved.

Keywords: assistive devices, visually impaired, electronic travel aids, hazards, obstacle detection, ground condition detection

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One of humans' most prominent senses is vision due to how essential it is in our day-to-day lives. The World Health Organization (WHO) reported 2.2 billion people with visual impairments in 2018, with about 1 billion of those people having a moderate to severe impairment. The high number of individuals with visual impairments present the need for assistive devices to help this population. Detecting the surrounding environment can be difficult for persons with visual impairments and can regularly lead to injury from misidentification of obstacles. Furthermore, visual impairment increases the difficulty of detecting stairs, holes, puddles, and other similar. Commuting becomes very difficult which can result in a loss of independence from persons with visual impairment (Shah et al., 2021). Finding effective solutions for navigation for the visually impaired has become the main focus of many technologies.

Section 1: Current Devices and Solutions

There are a few traditional solutions that aim to solve the issues of persons with visual impairment. Of these, there are the white cane, the guide dog, and TGSI.

1.1: White Cane

The white cane is the most common solution persons with visual impairment use to navigate without assistance. White canes come in long or short sizes and many different styles (Nichols, 2010). Some are able to be folded, some collapsed, and others have no way of compressing in size. Some people with visual impairments are also not properly trained in the

usage of a long straight cane, which can cause injury. However, this long cane tends to be the safest option when used properly (Nichols, 2010). Out of all the options that will be discussed it is generally considered the easiest to use (Nichols, 2010). The white cane alerts the user of obstacles in front of them, although the main issue is its limited range (Nichols, 2010). The limited range of the white cane also contributes to difficulty in detecting stairs (Nichols, 2010). Continually, white canes are unable to effectively alert the user of hazardous ground conditions such as puddles or uneven surfaces. While white canes see widespread use among individuals with visual impairments, there are many places where they could be improved.

1.2: Guide Dog

Guide dogs are another effective method to help the visually impaired safely navigate. About 5% of those with severe visual impairment use a guide dog (*Guide Dogs*, n.d.). They are typically used without the added assistance of a white cane and take verbal commands from their owner to get them to their destination (*Guide Dogs*, n.d.). Each guide dog is specially trained for its owner and the common dog breeds include golden retrievers and german shepherds (*Guide Dogs*, n.d.). Guide dogs can help owners avoid hazards such as obstacles and unsafe road conditions, but they are not an effective solution for widespread use. Due to the extensive training required and limited dog breeds that are capable, it is hard to produce new guide dogs for those that need them. The guide dog users also have to be trained and not all visually impaired are willing to take on the responsibility of taking care of an animal. While guide dogs do work well for those with visual impairment, more accessible solutions are necessary.

1.3: Tactile Ground Surface Indicators

While there are many other actively used solutions to help the visually impaired, one of the most common solutions used in cities to help specifically with permanent hazards are tactile ground surface indicators (TGSI). They are typically bright yellow and consist of many raised bumps so that a person with visual impairment could detect the surface with a white cane or just with their feet (*Tactile Ground Surface Indicators, TGSI, Tactile Surface Indicator*, n.d.). These provide safety and help people with visual impairment to identify train/subway station platform edges, pedestrian crossings, stairs, lifts, ramps, and escalators (*Tactile Ground Surface Indicators, TGSI, Tactile Surface Indicator*, n.d.). While TGSIs are effective where they are implemented, they are also not a universal or portable system and people with visual impairment cannot be certain that they will always be adequately alerted with this system.

Section 2: Research and Other Devices

2.1: Types of Devices and Examples

Assistive devices for the visually impaired come in many different functions. Some, like braille translators and printers, are used to help the blind with written communication by making braille easily printable, converting it into ink or text, or converting words into braille from pdfs or websites (*Braille Translators*, n.d.). Other devices could simply be optical aids. If an individual has a visual impairment, it does not necessarily mean they are completely blind. Some devices, such as distance magnifiers or minifiers, help those with specific near or far sight impairments. These are just a few of the examples of types of devices for the visually impaired (National Research Council (US) Working Group on Mobility Aids for the Visually Impaired and

Blind, 1986). However, the primary focus of this review will be to discuss the certain category of Electronic Travel Aids.

2.2: Electronic Travel Aids (ETAs)

Electronic Travel Aids (ETAs) are devices that help with orientation to allow the user to effectively travel from one place to another (National Research Council (US) Working Group on Mobility Aids for the Visually Impaired and Blind, 1986). Orientation in this case is used to describe both area familiarization and navigation. There are two devices that are currently most commonly commercially used. These include the Ray Electronic Mobility Aid for the Blind and the UltraCane. The Ray Mobility Aid is for use within 9.35 feet and produces an audible signal or vibration when an obstacle is close (*MaxiAids | Ray Electronic Mobility Aid for the Blind*, n.d.). However, this device does not detect drop-offs or non-obstacle hazards (*MaxiAids | Ray Electronic Mobility Aid for the Blind*, n.d.). It's also incredibly expensive, and costs $299, not including tax (*MaxiAids | Ray Electronic Mobility Aid for the Blind*, n.d.). The UltraCane is an alternative that is typically seen as more effective than the Ray Mobility Aid, but it is also rather expensive. The diagram below shows the range of obstacle detection for the cane.

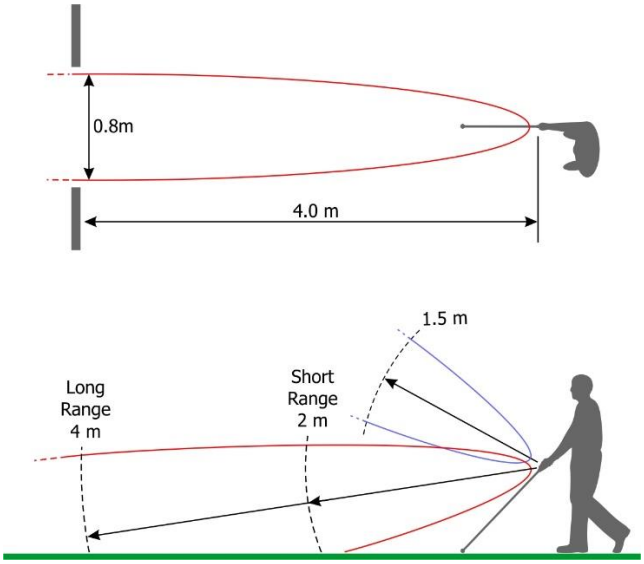

Figure 1: UltraCane Detection Range. This diagram shows and labels the different obstacle detection ranges for the sensors on the UltraCane (UltraCane, 2019).

The UltraCane is meant to simulate a mental map through its vibration feedback and allow the user to make quick decisions (UltraCane, 2019). However, the $600 price means that this is not an option for many of the blind who do not have the money or are not comfortable being responsible for an expensive piece of technology (UltraCane, 2019). Many studies have looked into the creation of ETAs with different methods of obstacle detection. The most common method of obstacle detection, and that used by most commercial products, is through the use of ultrasonic sensors (National Research Council (US) Working Group on Mobility Aids for the Visually Impaired and Blind, 1986). An ultrasonic sensor is an electronic device that measures the distance from objects by emitting ultrasonic sound waves and recording the time it takes the wave to travel back to the sensor (Jost, 2019). As many ETAs only focus on obstacle detection, this kind of sensor is able to provide all of the necessary data. Research on the

creation of new ETAs has focused on how other sensors can be applied for the same purpose. The purpose of this is typically to lower the cost or increase the accuracy of devices.

Section 3: Common Issues with Devices

While there are a few commonly used Electronic Travel Aids, there are also many examples of both experimental and commercial ETAs for which research has not continued or has not seen widespread use. This is due to a multitude of common flaws in this specific kind of assistive technology. The next few sections will discuss some of the different types of flaws.

3.1: Design and Comfort

Design and comfort flaws in Electronic Travel Aids typically deal with the physical aspects of the device. The most common kinds of complaints that fall under these categories have to deal with weight and size (National Research Council (US) Working Group on Mobility Aids for the Visually Impaired and Blind, 1986; Riazi et al., 2016). Ease of grip is also a widespread issue even though it is only present for handheld devices (National Research Council (US) Working Group on Mobility Aids for the Visually Impaired and Blind, 1986; Riazi et al., 2016). Fixing these issues, however, is a bit more difficult than it may sound. Many of the new technologies that would make detection features more effective also typically take up a lot of space (Prattico et al., 2013; Lee & Lee, 2011). Many new devices are made as white cane attachments, belts, or handheld devices (Prattico et al., 2013; Lee & Lee, 2011; National Research Council (US) Working Group on Mobility Aids for the Visually Impaired and Blind, 1986). Each of these options provides limited space for the necessary technology and can also

get bulky and awkward if too much weight is added. Creating an effective but compact device design is one of the main difficulties that come with building ETAs.

3.2: Learnability

New ETAs also typically have issues with their learnability. Learnability is how easy it is to acquire the skills to effectively use a device. This factor directly relates to the user and their personal opinion on the device. How easy it is to learn how to use a device is something that frequently comes up when surveys and testing is done on new devices (National Research Council (US) Working Group on Mobility Aids for the Visually Impaired and Blind, 1986). While this may not be a factor that affects long-term usage of a device, having a device that isn't easy to learn can deter new users and also negatively impacts initial testing feedback and/or results (Prattico et al., 2013; Lee & Lee, 2011, National Research Council (US) Working Group on Mobility Aids for the Visually Impaired and Blind, 1986).

Different devices use different kinds of feedback to alert the user of detected hazards. The two main feedback methods are audio and haptic (UltraCane, 2019; *MaxiAids | Ray Electronic Mobility Aid for the Blind*, n.d.). Audio feedback typically consists of different volumes or speeds of beeping for different kinds of alerts, while haptic feedback similarly uses vibrations (UltraCane, 2019; *MaxiAids | Ray Electronic Mobility Aid for the Blind*, n.d.). Neither one is necessarily better than the other. It all depends on what kind of device is being created and how easily the type of feedback chosen can be delivered to the user.

3.3: Capabilities

The final flaws in many ETAs come in their abilities, or more likely, lack thereof. Many devices, especially those with new technology, tend to focus on one specific feature rather than having a well-rounded device. Many try to fill gaps in the capabilities of existing solutions but do not end up joining the market because of failure to do so effectively and/or pricing. From Bing et al. (2020), it can be seen that many devices that are researched and created are not tested. The most common feature that ETAs work on including is obstacle detection (Bing et al., 2020, pp. 85–105). Despite the usage of different methods to include this feature, very few include other features that the visually impaired may find beneficial such as ground condition detection, GPS, or space perception (Bing et al., 2020, pp. 85–105; Riazi et al., 2016). This presents the need for more devices that have multiple capabilities while still addressing the many other issues that are present in many ETAs.

Conclusion

While a lot of work has been and is being done on devices for the visually impaired, significant improvements still need to be made for Electronic Travel Aids. Solutions such as the white cane, guide dog, and tactile ground surface indicators work, but provide a lot of room for improvement in the many areas in which they lack. However, current assistive device solutions are expensive and only include obstacle detection. Many new technologies have common flaws, such as weight, size, being hard to use, or also lacking features. All of this information presents the need for improved electronic travel aids for the visually impaired that consider the many flaws that have been found.

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