Wearable Virtual White Cane: Assistive Technology for Navigating the Visually Impaired[1]

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1 Background

Thirty-eight million people are visually impaired in the world. They encounter many disadvantages in mobility due to vision loss, which poses significant challenges when navigating unstructured environments. Conventional travel aids conveying simple tactile feedback to the visually impaired, such as fixed-length canes, provide limited ability to detect obstacles in a relatively limited distance. As a result, it can be difficult for the visually impaired to navigate smoothly using a cane.

Much research effort has been focused on developing electronic travel aids (ETAs). Computer vision-based ETAs [1–5] aim to help guide the user using specialized landmarks or predetermined features. The robustness of such devices is still questionable; for instance, the devices fail to provide navigation in scenarios lacking visual cues or repetitive features [1]. ETAs based on different sensing principles have been presented in literature to overcome these drawbacks. Palleja et al. recently developed a hand-held laser sensor based ETA device. The object detection signal is converted to pressure feedback generated by a belt on the user's wrist [6]. The limited scanning angle reduces region of interest for navigation. For other ETA devices like Miniguide [7] and the Nurion Laser Cane [8], the user needs intense focus and must intentionally sweep the device over the environment. To ease this inconvenience, Sonic Pathfinder [9,10] mounts an ultrasonic sonar ETA on a headband. The Pathfinder gives audio feedback in the form of notes on a musical scale, based on the proximity to objects ahead the user. Similar to other audio feedback designs [11,12], the major drawback is that audio signals can mask important environmental sounds. Although more complex to implement, devices relying on tactile sensation may thus present advantages.

In this work, we present a wearable and miniaturized ETA, called a wearable virtual cane network (WVCN). The device is hands-free and convenient for daily use, aiming to provide consistent and reliable guidance in various conditions.

2 Methods

The WVCN consists of four sensing units: two on the user's wrists, one on the waist, and one on ankle (Fig. 1(*a*)). This setup allows users' hands to be free at all times. Each unit (Fig. 2) uses ultrasound sonar technology to scan the surrounding environment. The unit casing houses a vibrating motor and a buzzer used to generate vibrotactile and audio feedback. The ultrasound sensor in the unit converts distance information to pulse-width modulation (PWM) signals sent to the Seeeduino microprocessor. The PWM duty cycle is altered as the distance between the obstacle and sensor changes. The wrist units are used to scan laterally, and the sensors on the waist and ankle detect objects in front of the user. As a user walks with a natural gait, the sensors automatically scan the environment and return environmental proximity information simultaneously. The subject navigates based on the feedback acquired from the four units. The sensors' status can be monitored on a smartphone via Bluetooth communication (Bluetooth Frame model: WLS31764P).

All units feature the same components, except for the omission of the buzzer and the volume control knob for the wrist units. The wrist devices can detect objects up to 480 cm away, with an adjustable range for indoor applications. The device on the waist is programmed to detect objects up to 220 cm. The unit provides spatial depth information by varying the intensity and frequency

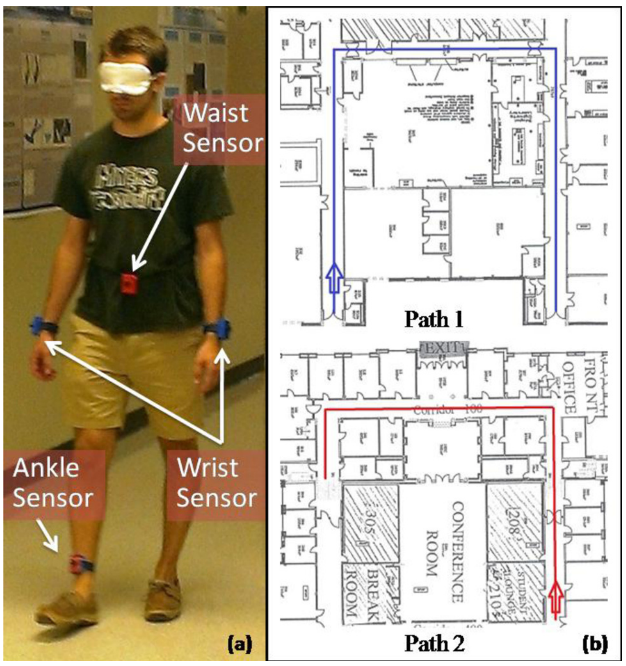

Fig. 1 (*a*) Four wearable units providing panoramic sensing data; (*b*) path 1 (blue) is 80 m long, where the subject encountered three T-junctions and made two right turns. Path 2 (red) is 65 m long with one T-junction, two left turns, and one set of stairs.

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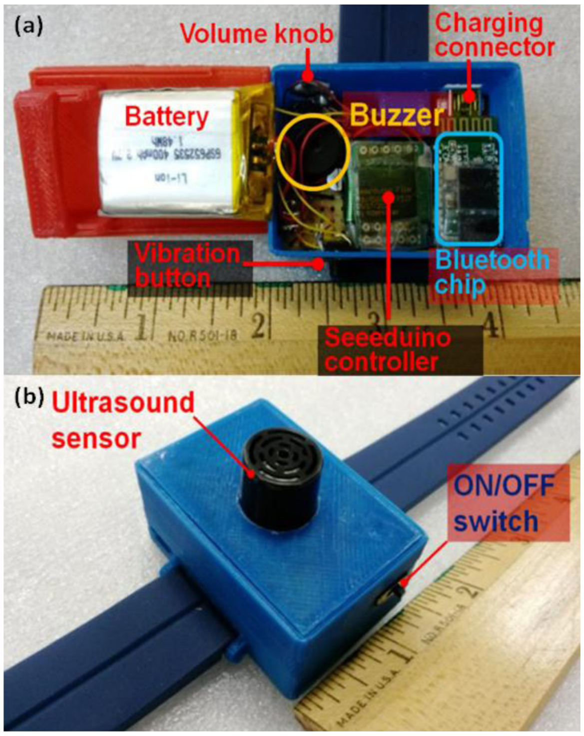

Fig. 2 **(*a*) Key components, along with wireless charging circuit held tightly in the box. The Seeeduino controller and audible buzzer are secured tightly on the printed circuit film. (*b*) The sensing unit in a small box (54 × 37 × 23 mm).**

of vibration and sound, which can be adjusted subject to the user's preferences. A 400 mAh lithium battery powers the cane for 5 h between charging cycles.

3 Results

Two navigation scenarios, path 1 and 2 (Fig. 1(*b*)), were simulated in an indoor environment to validate the practical value of using our proposed device. Five sighted subjects were blindfolded and navigate the two paths using (1) a standard white cane, (2) the WVCN, and (3) both the cane and the WVCN. The order of these three guidance modes was randomized to eliminate any order bias. The subjects were allowed to familiarize themselves with the device's operation as well as the two paths before starting navigation. Vibration and sound feedback levels were self-selected. Time needed to complete a path, the number of missed turns, and collisions with obstacles were recorded. Time to complete the paths for each guidance system was averaged across subjects to mitigate confounding effects. Figure 3 compares results between the three guidance systems. Generally, navigation using the WVCN required less time. The synergistic use of both a standard cane and the WVCN yields significant improvement, particularly in path 2, where the navigation scenario is complicated by a set of stairs.

4 Interpretation

The four-node wearable ETA device is proposed. A preliminary validation has been conducted to investigate its potential performance. The primary ongoing work is to simplify charging via wireless charging technology. The device will also be tested in visually impaired subjects to obtain more valuable feedback and data. Various navigation scenarios will be designed to further validate the device's practical value in daily use.

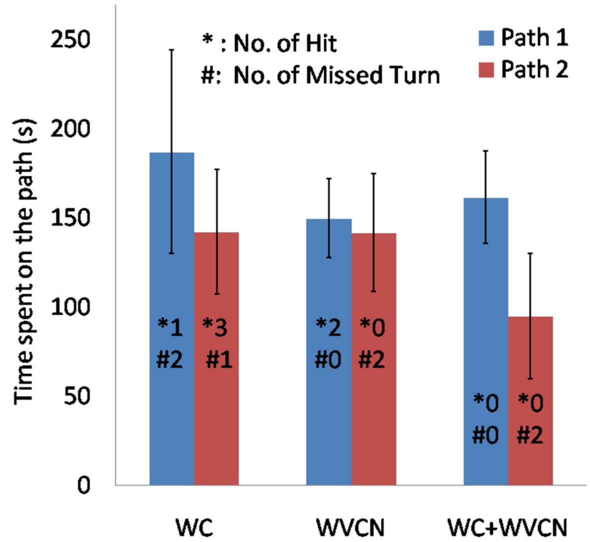

Fig. 3 **Average navigation time of five subjects**

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