Smartphone Haptic Feedback for Nonvisual Wayfinding

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ABSTRACT
We explore using vibration on a smartphone to provide turn-by-turn walking instructions to people with visual impairments. We present two novel feedback methods called *Wand* and *ScreenEdge* and compare them to a third method called *Pattern*. We built a prototype and conducted a user study where 8 participants walked along a pre-programmed route using the 3 vibration feedback methods and no audio output. Participants interpreted the feedback with an average error rate of just 4 percent. Most preferred the Pattern method, where patterns of vibrations indicate different directions, or the ScreenEdge method, where areas of the screen correspond to directions and touching them may induce vibration.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – *input devices and strategies.* K.4.2 [**Computers and society**]: Social issues – *assistive technologies for persons with disabilities*.

General Terms
Design, Human Factors.

Keywords
Haptic feedback, wayfinding, blind, accessibility.

1. INTRODUCTION
People with visual impairments experience challenges in wayfinding, the act of orienting and navigating in and through physical space. As such, many research and commercial systems have been developed to enable blind and low-vision people to navigate more independently. Most of these systems, however, primarily use speech output that can be distracting and difficult to hear in a loud environment. Since blind and low-vision people rely on their hearing to understand their surroundings, speech output can also be unsafe.

We explore ways of giving turn-by-turn routing instructions with haptic output, a safer and less distracting modality. We present our novel *Wand* and *ScreenEdge* feedback methods and evaluate them with the *Pattern* method, which is based on prior work [4,6]. All use the single vibration motor, compass, and touch screen on a relatively inexpensive smartphone. A navigation system can direct a user along a route with vibration using these methods instead of speaking the instructions. We built a prototype navigation system and conducted a user study with 8 blind people to compare Wand, ScreenEdge, and Pattern.

Our contributions include: (1) presenting two novel accessible techniques for providing navigation instructions (Wand and ScreenEdge); and (2) empirically comparing these methods to Pattern with blind and low-vision users.

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2. RELATED WORK
Most commercial and research wayfinding tools that provide nonvisual feedback use speech, but there has been some work on the use of haptic feedback for both blind and sighted users. Pielot and Boll [5] and Heuten *et al.* [3] used a tactile belt to convey directional feedback to users with visual impairments. Amemiya and Sugiyama [1] and Hemmert *et al.* [2] developed new vibrotactile feedback modalities to convey directions. Pattern, Wand, and ScreenEdge, in contrast, convey similar information but use commodity hardware that is cheaper and readily available. Jacob *et al.* [4] proposed using patterns to communicate directions but only described a case-study evaluation. Similarly, Pielot *et al*. [6] described using vibration patterns for sighted users. Our Pattern method is similar to methods used in [6] and [4] but the Wand and ScreenEdge methods are novel. Also, our work is the first to conduct a comparative evaluation of haptic wayfinding feedback for blind and low-vision users.

3. PROTOTYPE & FEEDBACK METHODS
In this section, we describe how the Wand, ScreenEdge, and Pattern methods provide navigation instructions to a user as she walks along a route. We built a prototype on a Motorola Droid phone. The built-in GPS is used to determine where the user is along a pre-programmed route and third-party routing API's are used to determine where she must turn at the nearest intersection. We focus on evaluating feedback methods, so our prototype is simple: it instructs the user which way to walk at the nearest intersection, assuming there are only four possibilities (forward, backward, right, or left). We defer incorporating vibration feedback into a more sophisticated navigation system to future work.

3.1 Wand
With the Wand technique, the user points the phone like a wand around him- or herself. When the top of the phone is roughly pointing in the direction where the user must walk, the phone will vibrate. The built-in compass is used to determine where the top of the phone is pointing.

3.2 ScreenEdge
The ScreenEdge method uses touch input and vibration output. With this technique, the user touches the screen near the four edges. The phone will vibrate when the user touches close to the edge that corresponds to the direction he or she must walk at the next intersection. For example, if the phone vibrates when the user touches close to the top edge of the screen, the user must walk forward; if the phone vibrates when the user touches the screen near the right edge, the user must turn right. Unlike the Wand, the ScreenEdge does not use the compass so the direction indicated is relative the previous leg of the route.

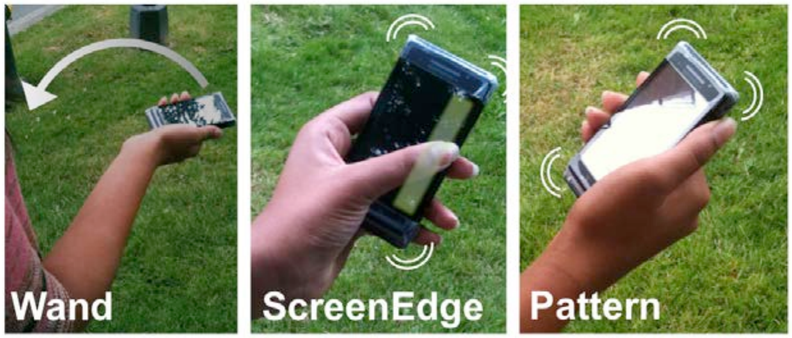

Figure 1. A participant uses the phone to determine which direction to turn. The tape at the top and bottom of the phone tactually marks the edges of the screen. In the ScreenEdge image, the highlighted area shows which region of the screen will induce vibration when the user must turn right.

3.3 Pattern

The Pattern method simply vibrates for 1 to 4 pulses to indicate which way a user must turn at the nearest intersection. One pulse indicates the user must go forward, 2 pulses indicate the user must turn right, 3 pulses indicate the user must turn back, and 4 pulses indicate the user must turn left. The phone vibrates when the user presses one of the physical keys on the phone (we used the volume key in our implementation). As this method does not use the compass, Pattern indicates directions relative to the previous leg of the route.

4. EVALUATION

4.1 Participants and Methods

We conducted a within-subjects user study with 8 blind and low-vision participants (6 females, 2 males, mean age was 53) to compare the Wand, ScreenEdge, and Pattern methods. With each participant, we briefly explained each method, and conducted a lab test, a field test, and an interview.

During the lab test, each participant was asked to interpret feedback 4 times with each of the 3 methods while standing or sitting in one place. For example, we programmed our prototype to instruct the user to turn right using the ScreenEdge method, handed the phone to the participant, and asked him or her to tell us in which direction the phone instructed the participant to walk. We then conducted the field test, which involved walking along a pre-programmed route in a busy urban area. The route included 16 intersections where the participant used the phone to determine in which direction to continue walking. We used a different feedback method for each consecutive group of 4 intersections. We randomized the order of feedback methods to avoid bias. Finally, we conducted an interview with each participant that included the NASA-TLX tool for assessing the workload of using each feedback method.

4.2 Results

Accuracy was high for all methods. On average, participants erred 0.75 out of 8 times when using Wand (9%), 0.13 out of 8 times when using ScreenEdge (2%), and 0.13 out of 8 times when using Pattern (2%). Twenty-five percent of errors made when using the Wand occurred because the phone's compass was inaccurate in certain locations.

Four out of the 8 participants preferred using Pattern, while 3 preferred using ScreenEdge, and none preferred using Wand. One participant preferred either ScreenEdge or Wand. Participants felt that the Pattern method was fastest and some liked the tactile interaction in ScreenEdge. Moving the phone around in Wand was uncomfortable for some participants, and they found this method less reliable. According to the NASA TLX questionnaires, all participants assessed the workload of Wand to be higher than that of ScreenEdge or Pattern, while workload assessments between the latter two methods varied. All participants indicated that they liked receiving navigation instructions through vibration and found all three methods to be effective.

5. CONCLUSION

We have developed and evaluated three methods for giving blind and low-vision people walking directions using vibration on a smartphone. Our user study demonstrates that all methods are viable means of communicating directional information without demanding a user's auditory attention or requiring special hardware. There were some reliability issues with the smartphone's built-in compass, however, which we hope to remedy in future work. Also, we plan to incorporate the methods presented here in a more sophisticated navigation system.

6. ACKNOWLEDGMENTS

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