PocketNavigator: Vibro-Tactile Waypoint Navigation for Everyday Mobile Devices

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ABSTRACT

Pedestrian navigation systems are becoming popular but the currently dominant audio-visual interaction can have drawbacks. Tactile feedback is studied as a solution, but currently only available as research prototypes. With the PocketNavigator we propose a demonstrator that adds tactile feedback to a simple but robust map-based navigation system that runs on any Android Smartphone. Users can leave the device in the pocket, while being guided non-visually through vibration cues. Like a compass we "point at" the next waypoint by encoding its direction and distance in vibration patterns. As an advantage over previous approaches it allows giving continuous feedback instead of isolated turning instructions and it can be realized without custom-built tactile displays. Preliminary results from a field study show that pedestrian can effectively use this *Tactile Compass* to reach a destination without turn-by-turn instructions. Integrated into the PocketNavigator we can now deploy it at the Android Market to evaluate the Tactile Compass with a wide range of users.

Categories and Subject Descriptors

H.5.2 [**User Interfaces**]: Haptic I/O; I.3.6 [**Methodology and Techniques**]: Interaction techniques

General Terms

Design, Experimentation, Human Factors

Keywords

Tactile Displays, Pedestrian Navigation

1. BACKGROUND AND MOTIVATION

With the success of high-end Smartphones, navigation systems for pedestrians have reached the end consumer market. The typical navigation system we find is a map-based system showing the user's current position on a map. Optionally, the route to the destination is highlighted. Instructions about how to turn at each crossing may be given by text or speech. A legitimate question is if this kind of information presentation is the right way to guide a pedestrian from A to B. It has been shown that interacting with a mobile device often happens in short bursts which results in fragmented attention [7]. Consequently this leads to decreased performance in reading a mobile device's screen while walking [1]. Auditory displays have been proposed a solution but require wearing headphones, which cut the user off of the environment (e.g. a chat with a friends), or require speakers, which may be found disturbing bystanders and/or embarrassing the user.

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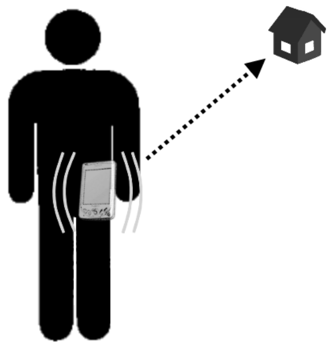

Figure 1: The basic idea: a "Tactile Compass" encodes - in vibration patterns generated by an everyday mobile phone - in which direction and how far a place is located from the perspective of the user.

As a solution to these problems the use of special tactile displays for (pedestrian) navigation support has been investigated by several groups [5, 8, 11, 12]. It has been shown that people can effectively be guided along a route with tactile displays [12] with a reduced cognitive workload compared to vision-based systems [3, 8]. They also can support interpreting map-based information [9, 10].

One limitation of the above work is that custom tactile displays were used, which are typically not available to the wider public. The use of existing tactile displays has rarely been studied. As an exception, Lin et al. [5] proposed to encode turn-by-turn instructions via a phone's vibration motor. In a pilot study they found that tactile patterns could effectively issue a small set of turning instructions.

An open question is if the advantages of tactile displays for pedestrian navigation would exist in-situ beyond the setting of a fields study. With this demonstrator, the PocketNavigator, we present a tool to investigate these questions. The PocketNavigator is a simple pedestrian navigation application for Android phones that incorporates tactile feedback for supporting the navigation. The tactile feedback is used to encode the direction of the next waypoint, similar to a compass. Thus, the user just needs to follow the direction the Tactile Compass presents until reaching the destination. As advancement over the turning instructions proposed by Lin et al. [5] this compass-like information presentation is continuously available, not only when the user reaches the crossing. Preliminary results of a field study show that people can effectively reach their destinations with that Tactile Compass. By the time of writing the PocketNavigator is available at the Android Market[1] to evaluate the Tactile Compass with a wide range of users. Inspired by current studies [4, 6] we use the Market to run worldwide trials "in the wild".

2. THE POCKETNAVIGATOR

In order to investigate tactile feedback in-situ we had to find an interaction technique based on a tactile display that can be issued to a wide range of informants. The goal was to provide directional, compass-like information such as the tactile displays used in previous studies [8, 11, 12] to support pedestrian navigation via the sense of touch. The second goal was to realize that information presentation with the tactile display that is most widely available: the mobile phones vibration motor.

As navigation platform to deploy the tactile navigation technique we developed the PocketNavigator. The PocketNavigator is a simple map-based navigation system for Android phones. Similar to the interactive maps (e.g. Google Maps or Nokia Maps) found on today's Smartphone devices it shows the user's position on a layer of pre-rendered map tiles (see Figure 2). By double-tapping any location on the map a route is calculated to this position originating from the user's location. The route is then drawn into the map and the next waypoint is highlighted. Once the route has entered, the goal was enabling the user to reach the destination leaving the device in the pocket.

2.1 The Tactile Compass

For realising the tactile cues we drew on the metaphor of a compass. Instead if providing turning directions (e.g "in 50m, turn left") it presents the direction and distance of the next waypoint (e.g. "the waypoint is 500m straight ahead of you"). The user is continuously told in which direction to go, not how to turn at a certain decision point (See Figure 3). This has the advantage that compass information can be presented continuously so the user receives constant confirmation.

We encoded direction and distance by drawing on the Tactons framework [2]. Tactons are tactile icons that encode one or several dimensions of information in different parameters of a tactile stimulus. Parameters studied to encode information dimensions in Tactons are duration, amplitude, frequency, waveform, location on the body location, and rhythm. An example by [2] is to encode the type of an incoming cell phone call in the waveforms and the urgency in different rhythms. Since typical vibration motors in mobile phone can only be turned on and off, we had to stick to the parameters duration and rhythm for our design. In our case we aimed at encoding the dimensions of direction and distance by these two parameters.

[1] `http://www.android.com/market/`

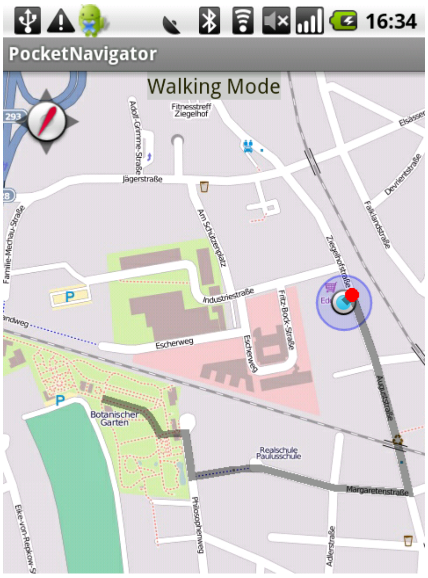

Figure 2: A screenshot of the PocketNavigator's main view: similarly to many map-based navigation systems the user's position if show on a map (here OpenStreetMap.org) and optionally the current route is highlighted.

The resulting set of Tactons is called TwoPulse. It uses two pulses to encode the direction of the waypoint in relation to the user's heading. Two equally short pulses indicate that the waypoint is straight ahead. If the waypoint is to the left, the first pulse becomes longer. Similarly, if the waypoint is to the right, the second pulse becomes longer. The longer the "long" pulse becomes the further left/right the waypoint is. As an exception, three pulses encode that the waypoint is behind the user. These Tactons are visualised in Figure 4.

The distance to a waypoint is encoded in the duration of the pause between a pair of pulses: the closer the waypoint is, the shorter the pause becomes (see Figure 4).

2.2 Scanning versus Pocket

In order to make it easier for the user to interpret the directional information, the direction is presented in relation to the user's orientation. To obtain the user's orientation, two different methods are used: the GPS heading and the internal compass.

The GPS heading is the primary means for obtaining the user's orientation. Thus, the direction of the waypoint is displayed relative to the walking direction. The advantage this method is independent from the orientation of the mobile device. The device can be stored in the pocket in any orientation (see Figure 6). The disadvantages are that the user has to move in order to obtain the correct reference orientation. In order to avoid confusion we therefore mute the Tactile Compass if the user stops.

To get more immediate feedback we allow the user to scan for the next waypoint. If the device is being held parallel to the ground it uses the device's compass to obtain into which direction the top of the device is pointing. The device then can be used like a pointer (see Figure 7). In this mode the vibration patterns are repeated more quickly to

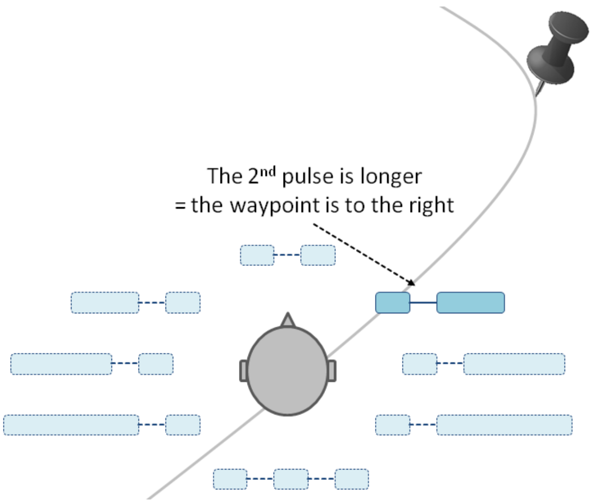

Figure 3: Instead of giving turning instructions, such as ”turn left now”, the PocketNavigator uses a Tactile Compass to point towards the current waypoint. By walking into the pointing direction the user is guided from one waypoint to another until reaching the destination.

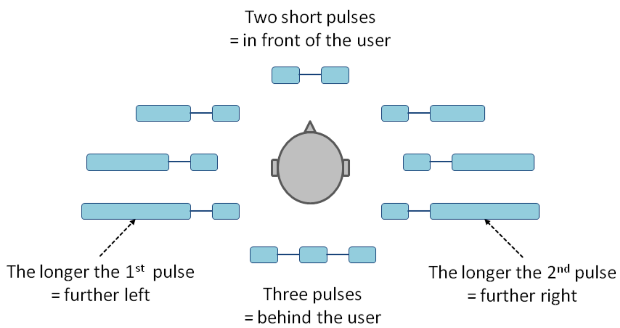

Figure 4: *TwoPulse* direction encoding: the direction in which the waypoint is encoded in the relative length of two pulses. The further left/right the waypoint is the longer the first/second pulse becomes.

make it easier for the user to scan for the current waypoint. The advantage of this mode is that the feedback is more direct and thus simplify locating the current waypoint. It also is more suited for demonstrating or learning the vibration patterns of the Tactile Compass. The disadvantage is that the device has to be used like a pointer which is more obtrusive and less private.

2.3 Field Test

To investigate if pedestrians can effectively interpret these vibration patterns and use it for navigation we conducted a field study. 14 participants had to reach 3 different destinations in a city forest. For each destination, they either used the map, the Tactile Compass only, or both. The order of use was counter-balanced to cancel out sequence effects.

In contrast to the mode of operation illustrated in Figure 3 only the location of the destination was displayed, as shown in Figure 8. This means that the participants had to find their own route to the destination. This could involve

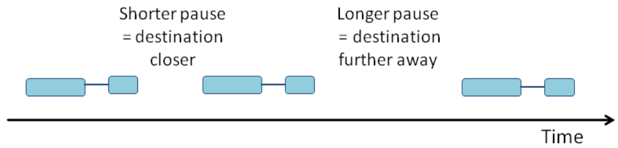

Figure 5: *TwoPulse* distance encoding: the distance to the waypoint is encoded in the pause between the sets of waypoints. The shorter the pause, the closer the user is to the waypoint.

Figure 6: In most cases the user just leaves the device in the pocket. The user's heading is then obtained from the GPS signal. Direction and distance of the next waypoint in relation to the user's heading and position is then displayed via *TwoPulse*.

e.g. going westwards although the Tactile Compass pointed north. For each of the navigation aids, we measured how fast the participants reached the destination, how much they visibly interacted with the mobile device, and well they were able to spot salient objects that were spread all over the forest.

The preliminary results show that people can effectively reach destinations being displayed by the Tactile Compass only. Furthermore, when using the Tactile Compass there was significant less visible interaction with the mobile device. However, we could neither find a significant difference in the number of spotted salient objects nor in the time to reach the destination between the three conditions. In summary, these results indicate that the Tactile Compass allows reaching a displayed location with no notable disadvantage compared to a map while offering a more privacy-respectful interaction.

3. CONCLUSIONS AND FUTURE WORK

In this paper we presented the PocketNavigator demonstrator, a map-based pedestrian navigation system that uses tactile feedback to guide the user along a route. The key feature of the PocketNavigator is the Tactile Compass that provides continuous directional information, such as a compass, through vibration patterns, and that these patterns can be realised with the vibration motors of common mobile phones. A preliminary field test indicates that people

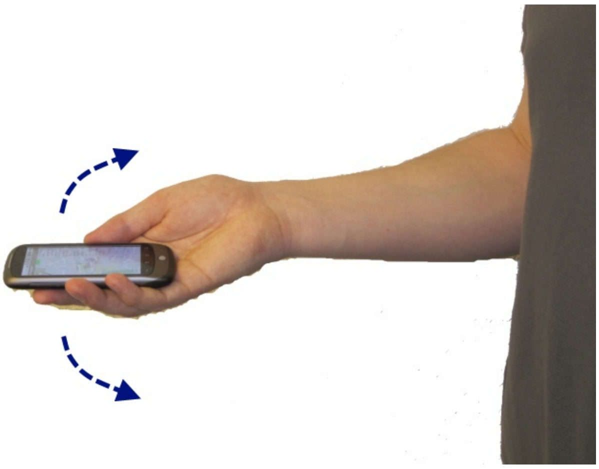

Figure 7: If the user is uncertain about the displayed information s/he can take out the device and "scan" for the next waypoint by pointing gestures. The direction of the waypoint relative to the pointing direction is displayed by *TwoPulse* as well.

Figure 8: In the field test, the Tactile Compass pointed straight at the destination. Still, users were able to the destinations as effective as with a map.

can reach destinations quite effectively by the Tactile Compass only.

In our future work we will investigate if the advantages of tactile feedback found in previous studies [3, 8, 12] can be confirmed "in the wild". Therefore, the PocketNavigator is published through the Android Market[2]. We aim at learning if users can understand the vibration patterns without having it explained by a person and if they use the tactile feedback for non-visual guidance. We also aim at understanding if the positive effects reported in the previous work also occur in-situ.

In order to investigate these questions we integrated an evaluation toolkit into the PocketNavigator. Like the studies by Henze et al. [4] and McMillan et al. [6] we log the use of the navigation devices. In contrast to these studies we employ activity recognition methods to understand the use of the Tactile Compass when navigating. We try to investigate usage patterns similar to those investigated in previous field studies [8, 9].

[2] `http://www.android.com/market/`

4. ACKNOWLEDGMENTS

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