Navibration Belt: A vibrotactile waist belt for directional navigation

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Abstract

Tactile feedback offers the possibility to reduce the amount of focus needed by a user to perceive necessary directional changes in navigation systems. In this work, we developed a vibrotactile waist belt that uses vibration motors to translate directional to tactile information, while an Android application is used for entering the destination. In a user study with four participants we evaluate our prototype by using the Photo Elicitation Method including picture-taking and thorough interviews. While some possible areas of improvement are revealed, the vibrotactile belt helps navigating without having to pay too much attention on the map and is generally well-received by our test participants.

Author Keywords

Way finding; pedestrian navigation; vibrotactile belt; ubiquitous computing

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction

In the last decades, electronic navigation devices to improve way finding have become more and more important and common. Car drivers, bicycle riders or pedestrians increasingly rely on them to reach desired destinations. With the soaring prevalence of smartphones, tablets and other small high-technology devices, GPS navigation found its way into nearly every pocket or purse. While it is easy to enter a desired destination and display a map with the current position and directions, the attention required to watch for directional changes is high. In addition, visually-impaired individuals or car drivers/bicycle riders are generally not able to perceive visual cues. While there is the possibility of audio (speech) output, it still requires a high amount of focus.

Tactile feedback from a wearable device is a way of avoiding these problems, as users do not have to actively focus on possible directional changes. We built a vibrotactile waist belt that translates directional in tactile information with the help of three tactors. A custom android app is used for entering a desired destination, while the integrated GPS receiver and/or available wireless networks are used to determine the current position. However, the user does not have to focus on the smartphone after entering the destination, as directional information is wirelessly transmitted to the vibrotactile belt, where the corresponding tactor notifies him/her of a directional change.

Related Works

In [8] Zhang et al. discussed navigation systems for persons with visual impairment, which is obviously an important target group for vibrotactile devices. While our prototype is not specifically targeted at the visually impaired, the general introduction to sensory substitution helped us gain basic knowledge about this research area. The authors of [5] evaluated three different wearable interfaces for orientation and way finding: a sonic guide, speech output and a shoulder-tapping system, where vibrotactile pads are placed in a backpack to communicate directional information. The evaluations of the sonic guide and the speech output solutions led us to believe that acoustic feedback is not superior to common navigation devices as it requires a high amount of focus from the user.

In [7] Van Erp et al. investigated waypoint navigation with a vibrotactile waist belt that consists of eight tractors. Amongst other things, they evaluated the usefulness of translating distance to vibration rhythm and discovered that it does not improve the way finding performance; therefore we decided to disregard this aspect. In [4] a vibrotactile waist belt for enhanced environmental perception was introduced. It uses ultrasonic sensors and eight tactors to improve safe movement under conditions of poor visibility. The authors of [3] used a similar belt with 6 tactors to help a user determine his/her position and orientation while using a common paper map. This inspired us to work on a way to map the current orientation to tactile feedback. Unfortunately we were not able to acquire the necessary hardware (such as a compass for Arduino) to implement this feature.

In [6] the “ActiveBelt” device was presented, a “wearable tactile display for directional navigation”. The vibrotactile waist belt consists of eight actuators and translates directional to tactile information. This research inspired our prototype in many ways.

The Navibration Belt Prototype

Concept

The Navibration Belt is supposed to shift notification of directional changes in navigation systems from visual/auditory to tactile cues to decrease the required attention. The belt is comfortable to wear and completely mobile, so no wires (additional to those directly attached to the belt) or additional equipment (besides a mobile phone) are necessary. In the primary application, which is installed on the user's smartphone, a familiar navigation map with the possibility to enter a destination is displayed. The internal GPS receiver and available wireless networks are used to determine and display the current position. Important waypoints (crossroads) are displayed as well as a full path to the desired destination. To further increase the comfort of usage, the continuous transmission of data from the phone to the belt works wirelessly via Bluetooth. If the navigation is active, whenever the user approaches a crossroad, the required directional change is provided through one of the tactors that are attached to the waist belt (left, right, front). If the desired destination is reached, all three motors vibrate to notify the user.

Technical implementation

An Android application is used for general data input such as entering the desired destination. The phone is required to have an internal GPS receiver as it is used to determine the current position and therefore updating directional information. The Google Maps API-Web Services [2] are used for obtaining the displayed map as well as navigational data such as geographical coordinates of waypoints and general directions.

The Navibration Belt itself consists of an Arduino Mega that gets power from a battery pack (see Figure 1). It has three vibration motors (left, right and front) attached to it that are fixated at the corresponding belt positions. We also use a Bluetooth module for wireless communication with the smart phone.

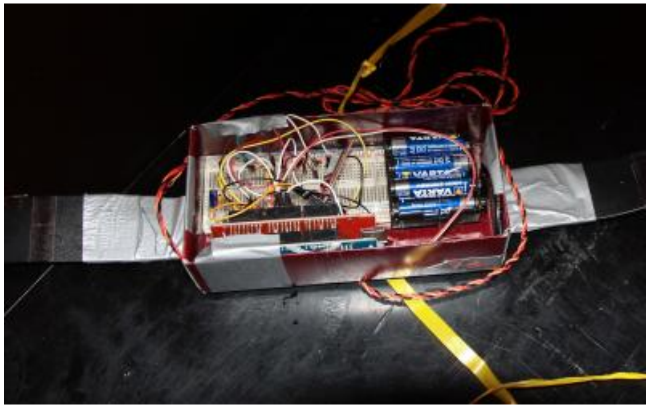

Figure 1. Picture of the prototype hardware. Detailed view of the attached storage box containing the Arduino, a battery pack, the Bluetooth module and required wiring.

In the Android application, the Amarino Library [1] and application is used for connecting the phone to the specific Arduino and sending special flags (consist of a single char) via Bluetooth. Whenever the user's distance to the next waypoint is under a certain threshold (30m in the current implementation), a flag is sent ("r" for right, "l" for left, "g" for straight ahead). Upon receiving them, the Arduino activates the corresponding vibration motor for five seconds. If a "t"-flag is received (which indicates that the desired destination is reached), all three motors vibrate for five seconds.

User Study

We tested and evaluated our prototype with four participants, all male and between 20 and 30 years old. All four of them are acquaintances of the researchers and voluntarily participated in our evaluation. Table 1 lists all relevant information.

Participant	**1**	**2**	**3**	**4**
Sex	male	male	male	male
Age	23	24	??	??
Test duration	3h	3h	??	??
Test location (Vienna)	Wieden	Wieden	Heiligen-stadt	Heiligen-stadt
Movement	by foot	by foot	by foot	by foot
Method	PEM2	PEM2	PEM	PEM

Table 1. User study participants and relevant attributes. PEM is the Photo Elicitation Method with a normal camera, while in PEM2, the participants were making pictures with the BTC application on a smartphone.

All participants used the belt outdoors, as the location provided by indoor wireless networks is far less accurate than the position service provided by GPS satellites and we did not want external factors to disturb the study. We also decided to only let the participants test our prototype by foot and not include driving or cycling as in its current state the Navibration Belt is primarily focused on providing directional feedback to pedestrians. In future studies though, using our vibrotactile waist belt while driving by car or riding a bicycle could also be interesting use cases.

We chose the Photo Elicitation Method (PEM) as our evaluation method which is explained as follows. After explaining the functionality and general usage of our prototype to the participants, we handed them a camera and asked them to take pictures of the system and/or their interaction with the system whenever they feel like there is something interesting going on. They were heavily encouraged to make as many pictures as they like while they explore all aspects of our technology. While participants 3 and 4 received a common camera, participants 1 and 2 were handed a smartphone and were asked to make their pictures using the "Behind The Camera" (BTC) application that simultaneously shoots a photo with the phone's front and back camera (PEM2). They then received as much time as they want to test our prototype; this usually led to two to four walks lasting one to three hours in total. After that, we did a photo elicitation interview with each participant, in which they walked us through their photos and explained their findings. The session was recorded on video for further analysis.

Findings

During the interviews, we were able to extract important feedback on many aspects of our prototype that is categorized in this section. Although the main focus of the user study lay in evaluating the quality of the tactile feedback itself, we also received some notes on the Android application and the belts visual appearance.

Robustness

Just after participant 1 started his first test run with our prototype, he told us that only one of the three vibration motors was actually working. After examining the belt, we discovered that some wires unplugged themselves during transportation. While this was the only time during the user study that something like this happened, apparently the general robustness of the wiring needs improvement.

Figure 2. Picture of the box taken by participant 1. View of belt worn by participant 1 (left) and back camera showing nothing special (right). While the belt itself is pretty comfortable, participants pointed out that the box containing the Arduino on the back could be smaller.

Wearing comfort

All participants noted that the belt itself is comfortable to wear and easy to put on. Participants 2, 3 and 4 did feel as though the box on the back, which is containing the Arduino, could be smaller, as it looks "a little bit odd" (see Figure 2). Participant 1 had a few problems hiding the ribbon that is currently used to keep the box from opening. On the other hand, he noted that he is enjoying the fact that he does not have to hold the phone in his hand at all times and instead is able to put it in his pocket while still being able to receive information on directional changes.

Vibration intensity and duration

Participants 1 and 3 felt like the relatively high vibration intensity is just the right amount, as it makes it easier to feel the feedback even through thick clothes. Participants 4 suggested generally reducing the vibration strength, while participant 2 would prefer a continuously rising intensity to reduce the abruptness of the feedback. All participants were pleased with the fixed feedback duration of five seconds and perceived it as fitting.

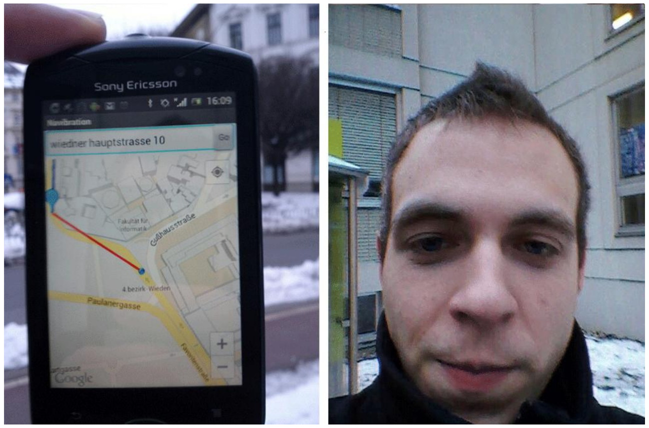

Figure 3. Picture of the application taken by participant 2. View of the Android application (left) and participant 2 (right). He noted that on this big crossroad the tactile feedback was a little bit ambiguous.

Time of tactile feedback

Participants 1, 3 and 4 noted that the required directional changes were correctly translated into tactile feedback and that they never had a problem with walking in the wrong direction or missing a branch. Participant 2 had a problematic experience on a big crossroad with more than four directions and some diagonal roads (see Figure 3). He noted that he received the feedback too early and while he was able to find the right way, it was difficult to map the vibration to one of the many directions. While participant 3 stated that the feedback came way earlier than he thought it would, he did not consider it being a problem. Participant 1 noted that it would be beneficial to get directional information through tactile feedback right at the beginning, as this is currently not the case and it could lead to confusion in reaching the first waypoint.

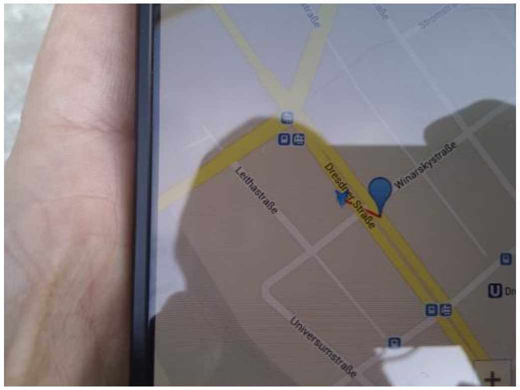

Figure 4. Picture of the application taken by participant 3. Participant 3 pointed out that the destination was incorrectly assumed to be on the opposite side of the road.

All four participants correctly associated the vibration of all three motors as reaching their destination, although they all had slight problems finding the exact address. Participant 1 pointed out that the feedback came too early, because although he was in front of the right block, the exact address was still a few meters away. Participants 2 and 3 were on the wrong side of the road when all three tactors vibrated (see Figure 4). Participant 4 stated that in one test walk, when he wanted to get to a metro station, the goal was assumed to be right on the subway rails, which were impossible to reach.

Android application

The smartphone application did not arise any major problems for any participant. Participant 2 specifically noted that it is easy to understand because of the interface similarity to Google's “Maps” Application. Some minor flaws were experienced by participants 3 and 4, as they entered their desired destination indoors, which led to incorrect waypoints. When repeating their input outdoors, the application worked as intended. Participant 1 pointed out that the markers were lost on one occasion where he accidentally entered landscape mode on his smartphone while having a look at the map.

Conclusion

During our user study, we discovered several areas of improvement. The general robustness of the technology could be improved, as the wires can occasionally unplug. It might be better to spread the necessary Arduino hardware across the whole belt surface instead of storing it all in one single attached box, because several participants described it as mildly disturbing. We discovered that it might be beneficial to use more than three tactors for crossroads with more than four exits. The tactile feedback itself was apparently a little bit too abrupt; this could be improved by reducing the overall vibration intensity or by continuously increasing it. However, the primary problem seems to be the notification of arrival at the desired destination. While the intensity and distribution of the feedback itself seems to be working, the distance at which the tactors vibrate has to be adjusted. It might be a good idea to slowly increase the vibration intensity while the user is getting closer to the target to improve guidance to the exact point of destination.

Apart from those slight problems, the main functions of the Navibration Belt were working as intended. Wearing the belt seemed to be comfortable and information on directional changes was correctly translated into vibrations. The participants seemed to generally enjoy navigating with the belt without having to look at their phone too much. Although we did not focus on the evaluation of the application too much, the feedback still suggested that a simple application largely based on Google`s “Maps” and “Navigation” applications offers the best user experience as it offers a very familiar environment that is easy to interact with.

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