"I Did It My Way": Moving Away from the Tyranny of Turn-by-Turn Pedestrian Navigation

Simon Robinson[1], Matt Jones[1],
Parisa Eslambolchilar[1], Roderick Murray-Smith[2,3], Mads Lindborg[3]

[1] Future Interaction Technology Lab
Swansea University, UK
{ cssimonr, csmatt, csparisa } @swan.ac.uk

[2] Dept. of Computing Science
University of Glasgow, UK
rod@dcs.gla.ac.uk

[3] Nokia Devices, Nokia Mobile Phones
Copenhagen, Denmark
mads.lindborg@nokia.com

ABSTRACT

In this article we describe a novel approach to pedestrian navigation using bearing-based haptic feedback. People are guided in the general direction of their destination via vibration, but additional exploratory navigation is stimulated by varying feedback based on the potential for taking alternative routes. We describe two mobile prototypes that were created to examine the possible benefits of the approach. The successful use of this exploratory navigation method is demonstrated in a realistic field trial, and we discuss the results and interesting participant behaviours that were recorded.

Categories and Subject Descriptors

H.5.2 [**User Interfaces**]: Haptic I/O; Prototyping; Interaction styles

General Terms

Design, Experimentation, Human Factors.

Keywords

Mobile, bearing-based, navigation, vibrotactile, GPS

1. INTRODUCTION

Turn-by-turn pedestrian navigation is now widely available in mobile devices. However, we believe these increasingly-ubiquitous mobile systems can often remove the wonder and enchantment of an individual's exploration, and have an impact on users' normal behaviour [2]. In this article we present a simpler method for pedestrian navigation that aims to free users from the need to look at a screen or be micro-managed by listening to turn-by-turn instructions. Our goal is to remove the division of attention between a navigation device and the real world it describes; instead we prompt users to fuse their view of a location with the feedback given, allowing a more engaging experience. Our approach removes the complexity of direction following, recognising that pedestrian navigation might often be more exploratory, taking place in semi-familiar places. This approach also has benefits in other scenarios, such as those locations with no defined waypoints for turn-by-turn navigation, or completely unfamiliar places, where context is important, and a person walking alone might take a different route than when walking with friends.

We envisage this approach not as a replacement for, but as a complement to current navigation systems. In situations where quickest time or shortest path are not particularly important, users might find it more enjoyable to turn off the demands of instruction-following. Instead, we imagine people wandering through and impulsively exploring the interesting places around them, but with occasional reassurance that they're heading in the right direction. Consider the following scenario, which illustrates the approach:

> *John is visiting Rome for the first time, and is looking forward to meeting some friends at a good local restaurant. Taking out his mobile, he sees the arranged meeting place just about 2km away. It's such a lovely spring day, so, with time to spare, he roams freely in the rough direction of his meet-up, taking in the maze of alleys and quirky shops all around him. After 10 minutes, he scans left to right; the device vibrates to reassure him he's still on course, and also indicates that there are many routes to his destination. It feels good finding his own way, so he continues to make his own choices, enjoying the area around him. A little later, he comes to a main junction. Should he turn left or right? He'd better get this right, he thinks. Scanning again, the vibration feedback is now more targeted, and he walks on with confidence...*

We built two mobile vibrotactile prototypes to explore this type of spontaneous navigation behaviour. The first of these–*static feedback*–provides directional assistance in the form of fixed size, low-resolution vibrotactile feedback. Pedestrians can casually scan to discover the direction of their destination using a handheld device, but the apparent width of the haptic target remains the same regardless of their surroundings. The second prototype–*dynamic feedback*–uses information about potential path choices in the vicinity of the user's current location to expand or contract the size of the feedback area, providing some indication of the degree of choice available when route finding.

2. BACKGROUND

It is well known that the use of mobile devices while moving can cause problems in situations where visual attention is necessary, and pedestrian navigation is a perfect example of this type of scenario. Seager [12] discusses many of the challenges in screen-based pedestrian navigation. Holland *et al.* [5] describe potential problems and offer a solution in the form of audio cues to guide users toward a destination. A similar approach was taken by Jones *et al.* [7] and Strachan *et al.* [16] by dynamically adapting the music that a user is listening to in order to guide them in a certain direction. While these approaches have shown promise, related early work has found that many users are reluctant to use headphones for this type of task [1], citing concerns about being recognised as tourists, or a feeling of isolation from the environment. Our approach helps

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to minimise these effects, using vibrotactile feedback to allow a less-restrictive interaction style.

Previous research has investigated the use of directional vibrotactile feedback as a navigational guide, with vest- or belt-based systems being the most common approach. Van Erp *et al.* [14], for example, studied several combinations of vibrational pulses, and were able to successfully guide users to walk between waypoints. A similar approach was taken by Johnson and Higgins [6], applying the technique to navigation for blind users. Their tactor belt was aimed at helping people avoid obstacles in their surroundings, motivated in part by a desire to lessen the effect of navigation on users' other activities. Our systems have a similar goal: allowing interaction with a navigation device to be thought of as a background task undertaken only when it is necessary or desirable, rather than providing feedback for slight path deviations or upcoming waypoints.

Many haptic navigation systems have used tactors in fairly fixed positions on the user's body, but handheld vibrotactile navigation has only emerged fairly recently. Lin *et al.* [8], for instance, provided navigational assistance via direction-specific tactons, finding that users were quite able to recognise the haptic cues and take appropriate paths through their environment. Our work, however, relates more closely to the bearing-based feedback used in [9], combined with the low-attention feedback aims of [13], and drawing upon previous research showing the benefits of handheld directional vibrotactile feedback while moving [11].

3. PROTOTYPE SYSTEMS

We created two prototypes to investigate this approach to navigation assistance. Our systems use a simple scanning gesture to browse for feedback, with the user holding a mobile device in-hand and feeling for navigation feedback whenever they like.

In our prototypes, the feedback is not given in a turn-by-turn fashion; rather we present directional vibration to indicate the bearing of the destination, and allow the user to make their own path choices. Previous work has investigated the use of a general directional cue for situations such as bike-based tourism [10], but we apply the technique to navigation while walking. We build upon recent work that investigated the use of handheld directional vibration as a casual method for organising group meetups [15], extending this concept to allow users to get a sense of the path choices around them. This approach, we believe, can offer the user more freedom where appropriate, providing opportunities for off-the-beaten-track exploration. Unlike some previous approaches ([16], for example, which provided feedback varying as function of possible paths) we do not give any indication of the distance of the target, focusing instead on the benefits of giving users familiar and always-available reassurance that they are heading in the right direction.

Our first prototype–*static feedback*–uses a fixed angular width for the feedback given, relying on the user to observe potential route options and make appropriate choices. The second prototype–*dynamic feedback*–varies the width of the feedback area to give more information about the user's immediate environment (as illustrated in Fig. 1). By incorporating this extra aspect, pedestrians are able to sense whether alternative routes are available, but are still free to pick their own path at any point.

3.1 Implementation

Our prototype systems were implemented using Nokia N95 mobile phones. For feedback and device movement sensing we used the SHAKE SK6 sensor pack [16]. The SK6 provides three-axis accelerometer, magnetometer and angular rate data, and incorporates a pager motor which we used to produce vibrotactile effects. GPS positioning was provided by the N95's onboard receiver. For

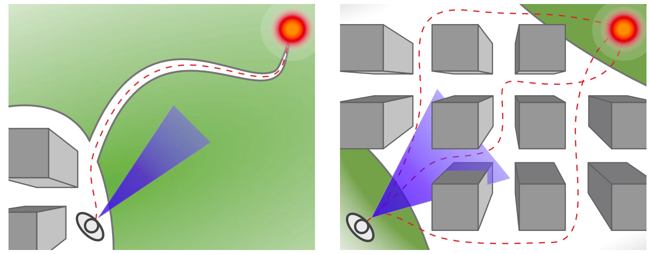

Figure 1: Dynamic feedback is directly related to path options. When fewer routes are available (left) the feedback area (shown in blue) is small, expanding when there is more choice (right). The centre of the feedback area aims directly at the goal.

this early prototype the N95 was worn on a lanyard around the neck, and the SK6 was held separately, attached to a dummy mobile phone. This was a design compromise chosen to minimise cross-device sensor interference while still providing a realistically-sized object that users could comfortably hold to feel for feedback.

The feedback used was designed based on previous research that showed that feedback can be a function of possible paths through the environment [16], and that vibrotactile angular widths need not be particularly small–indeed larger angular widths help to minimise user frustration, and have surprisingly minimal effects on user performance [15]. Our systems used the same minimum angular width of 60°, with the static feedback system using this at all times. The dynamic feedback approach altered the target width based on the number of potential alternative paths found. Pathfinding was achieved by precomputing a shortest path matrix using the Floyd-Warshall algorithm [4] on a graph of the study area. During actual usage, potential alternative routes were calculated by testing for paths from points in the area directly in front of the user's GPS trajectory. Routes that added more than 25% to the distance of the shortest path from the user's current location were discarded. The number of paths remaining was used to directly resize the feedback area, but this was limited to a maximum of 120° to avoid the excessively long routes that might result from edge-following behaviour.

4. EXPERIMENT

We conducted a field study to investigate the systems' effectiveness in a realistic navigation scenario. Our research questions were:

Viability: Can pedestrians navigate to a destination knowing only its general direction?

Freedom: Does the dynamic feedback prototype's coupling of feedback size to path variance have an impact on users' exploration of their surroundings while navigating?

After an initial pilot study, 24 participants aged from 18 to 65 were recruited for individual trials to help understand potential usage of the system. 14 participants were female, 10 were male; 13 were members of university staff, 11 were students. None of the participants worked in areas directly related to HCI.

Before the study each participant was randomly assigned to use one of the two prototypes. Fixed start and end points were chosen at the edges of the approximately 0.5km^2 study area, in order to give participants exposure to navigation with the system through both urban and rural areas. The straight-line distance between start and end points was 0.77km, and the shortest walking route (when keeping to paths) was approximately 1km. These well-spaced points allowed us to measure participant performance at a much greater distance than that commonly used between turn-by-turn waypoints.

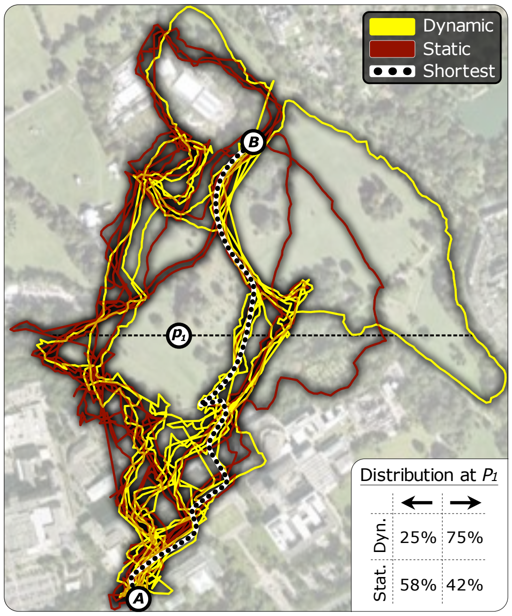

Figure 2: Routes taken from points *A* to *B* by all 24 participants during the study; shortest path overlaid. Inset: distribution between main routes. Participants feeling dynamic feedback tended toward the main campus thoroughfare; those feeling static feedback often took less familiar routes.

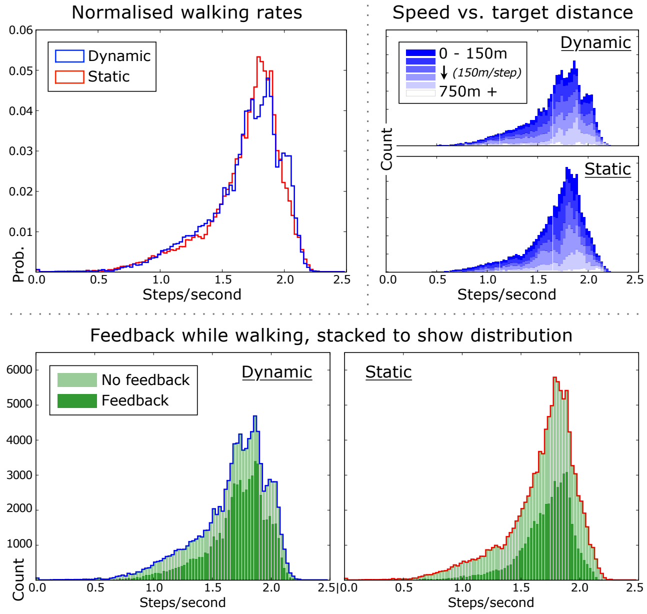

Figure 3: Top left: Walking speeds for each system: speeds are clearly similar. Top right: Walking speeds for 150m segments of the routes taken: similar rates were maintained throughout the task. Bottom: Walking speeds while the feedback was activated. Users walked and interacted simultaneously; those feeling the dynamic feedback interacted more, proportionally.

4.1 Measures

In addition to participants' comments and opinions in interviews, and recorded observations from the researcher running each trial, we collected detailed device logs allowing in-depth analysis of participant behaviours against our research questions.

Viability: We measured the success of the system as the overall percentage of participants who found their way to the end point. The viability of the system is reinforced by participant observations and remarks, and by looking closely at walking speeds, specifically the variance over the trial and the amount of stopping required.

Freedom: The freedom offered by the dynamic feedback prototype is measured by comparing the variation in paths taken by participants over both systems. In addition, comparison to results from our static feedback prototype allows a measure of the extra cost of any exploratory behaviour.

4.2 Procedure

At the start of each study session participants were met individually and led through an ethically-reviewed consent and user study guidance process. Participants were then talked through the concept and basic usage of the system they would be using, and given a short demonstration of the prototype. After a brief training session (less than ½ minute per user) in which they felt example feedback, participants were led to the pre-determined starting point on campus. When at the starting point, they began using the system to scan for and attempt to navigate to the end point. No description or guidance about the location of the end point was given, minimising potential effects from participants' prior knowledge of routes to the location. While navigating, participants were free to take any route they wished over the entire study area, while the researcher followed. Upon reaching the end point a short interview was conducted to gather opinions and experiences, and all participants were rewarded with a bookstore gift voucher as a token of appreciation.

5. RESULTS AND ANALYSIS

All participants successfully completed the navigation task and found the end point with only the vibrotactile feedback to guide them. Participants using the dynamic feedback system completed the navigation task in an average time of 17:24 minutes (sd: 5:25), while those using the static feedback took 19:02 minutes on average (sd: 5:36). The mean distances walked were 1.53km (sd: 0.39) and 1.65km (sd: 0.58) for the dynamic and static systems respectively, ranging from 0.97-2.39km for dynamic feedback and 1.08-2.93km for static feedback. Times and distances were not significantly different between feedback types (ANOVA, time: $p = 0.5$; distance: $p = 0.59$). Clearly users were able to navigate to the end point without the need for turn-by-turn guidance. The mean times taken and distances walked are longer than those for the shortest path, but the ranges of times, distances and routes taken (see Fig. 2) suggests that this has been as a result of the variance in path choices.

5.1 Path choices and walking speeds

Fig. 2 shows the routes taken by participants using each prototype, and also the shortest path – the likely route for a turn-by-turn navigation system. Interestingly, although both systems used the same destination point, many participants using the dynamic feedback have tended to stick more closely to the main thoroughfare of the university campus, while those using the static feedback have often taken a less well-trodden route. This suggests that the varying vibration has allowed users to combine the feedback given by the system with both the path cues in their immediate environment and any prior knowledge of the area, while participants using the static feedback felt obliged to follow the target direction more closely despite the (unknown) potential for a more appropriate route.

Using methods from [3] for gait phase analysis, we can look at participant walking behaviour in detail. As shown in Fig. 3 (top), there is very little difference in walking speeds between systems throughout the task, though those using the static feedback have a slight tendency to walk faster. When looking at walking rate against the feedback given (see Fig. 3 (bottom)), we can see that participants using the dynamic feedback have probed for feedback more of the time.

5.2 Participant observations and feedback

Participant observations confirm a tendency to walk at a steady pace for most of their route, with occasional pauses to check for confirmation at major path junctions. All participants except one enjoyed using the systems, and were surprised at their effectiveness despite some initial scepticism. Several participants remarked on the ability to "combine technology and knowledge of the environment to pick the right path", and that as they were in no hurry it was "good to be able to explore". Three participants said that they would not use haptics for navigation because they preferred to have constant knowledge of their position and destination. The participant who disliked using the system did not like holding the device constantly, but would have liked to repeat the trial with the device kept in a pocket to be used for occasional route updates. Half of the participants using the dynamic system explicitly commented that they liked the varying feedback, finding it helpful to know when they could take a different route; this seems to be reflected in their route choices. Most participants suggested potential use scenarios for this low-attention method of navigation, ranging from searching for catering venues to simple, low-cost tourist guides.

6. DISCUSSION

All participants were able to find an unknown target location with only directional vibrotactile feedback as a guide. The lack of turn-by-turn navigation guidance did not have a noticeable effect on walking behaviour, with brief pauses to check bearings being the only times participants stopped over the majority of routes. As can be seen in the walking data (and confirmed by participant observations) users preferred to keep track of the target direction most of the time, but were able to do this casually and without sacrificing attention. While the lack of waypoints might be an issue for navigation over much larger areas, users have had no trouble selecting appropriate routes over distances averaging at least 1.5km.

The variation in paths between users of the two systems shows interesting behaviours around commonly-travelled areas. We aimed to allow users more freedom in route finding while still being able to navigate to a target, and this is evident to some extent in the range of paths taken. Interestingly, many participants chose to follow familiar paths when given the option, though some outliers took the opportunity to explore an area they were not familiar with. Most kept to major paths while in a rural environment, but some (using either system) decided to take more direct routes (over wet parkland) when possible. This is an interesting behaviour, and not an aspect emphasised in our design process, though we suspect users might prefer actual paths when navigating to self-selected targets. In some cases these shortcuts have caused the participant to reach a dead end – this is an example of where our design does not offer the precision of a turn-by-turn navigation system. However, even in these cases users have managed to find the end point with no further assistance.

The use of variable feedback has been effective, and its benefits emerge when comparing the two systems. The times and distances recorded for each system are not significantly different, with no evidence to show that the less-precise dynamic feedback affected users' navigation ability; in fact, on average, users of the dynamic system found the target more quickly and in a shorter distance.

7. CONCLUSIONS

In this article we have explored, evaluated and discussed the application of bearing-based, low-resolution haptic feedback to real-world navigation. The promising results show potential for this type of system in the wild. Users successfully navigated to an unknown target while dealing with the complexities inherent in pedestrian navigation. Results from a prototype using fixed-size feedback support those of a similar system [15], and those from a more advanced prototype show the benefits of providing users with alternative path awareness via simple changes to angular feedback.

Acknowledgements

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