Guided by Touch: Tactile Pedestrian Navigation

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ABSTRACT

Haptics is a feedback technology that takes advantage of the human sense of touch by applying forces, vibrations, and/or motions to a haptic-enabled user device such as a mobile phone. In this paper we describe four haptic feedback-based prototypes for pedestrian navigation. Haptics is used to convey location, orientation, and distance information to users using pedestrian navigation applications. We compare the functionalities of four applications of haptics in such applications. Initial user trials have elicited positive responses from the users who see benefit in being provided with a “heads up” approach to mobile navigation.

Author Keywords

Haptic-feedback, pedestrian navigation, sense of touch, mobile devices, interfaces

ACM Classification Keywords

H.5.2 Information interfaces and presentation (e.g., HCI): Haptic I/O.

General Terms

Human Factors

INTRODUCTION

Increasingly GPS-enabled smartphones, such as Android and iPhone, are being used by citizens as location and navigational devices. Various commercial products like Navteq, Google and Bing are readily available in the marketplace for free download and use. These produces provide turn-by-turn navigation cues with distance and time information, usually on a map interface. Feedback to the user is provided in several ways: overlays on the map interface displaying the optimal path/route; audio feedback providing instructions; or textual display of the turn-by-turn instructions on path following. Unlike the closed environment inside a car pedestrians are in an open environment. They are not directly protected from the noises and distractions urban environments generate. When a user is walking, following turn-by-turn path instructions, it is very difficult for them to concentrate simultaneously on the mobile screen and the urban environment (pavement, shopping mall, etc) around them. Weather is also a factor. Rainy days or bright sunlight can make reading a mobile phone screen very difficult for some users. Audio feedback is a convenient alternative for providing user instructions [21] and can be used by using the phone’s speaker or by using a connected headphone set. Using a speaker could be impractical if the user is walking in a crowded, noisy, environment. Headphones provide a more subtle conduit for aural feedback. However headphone use can diminish the user *sense* or awareness of the environment around them such as moving vehicles, cyclists, etc. Overall visual and/or audio feedback is suitable for many practical situations but could be problematic in crowded urban environments.

Haptics or haptic technology is a tactile feedback technology that utilises of our sense of touch by applying forces, vibrations, and/or motions to the user through a device [34]. Substantial literature has been produced on this technology, such as [21, 34, 42, 3, 37, 38, 23, 10, 28]. These authors conclude that the sense of touch is advantageous in many situations when it is inconvenient or less appropriate to use either visual and/or audio feedback. Researchers, such as (Costanza et al [8] and van Erp et al [10]), stress that an interaction model for mobile device should: be customisable to meet the user’s requirements based on the activity the user is involved in, deliver easily understood cues, and should not overly interfere with the user’s current activity. In situations when vision-based or audio-based feedback for pedestrian navigation is in-appropriate we believe that haptics can provide feedback to users in the real world situations. In Jacob et al [24] we integrated a model of haptic-interaction (from earlier work in Jacob et al [23]) into pedestrian navigation applications on Android smartphones. This paper presents four haptic feedback-based prototypes we have developed for pedestrian navigation in the real-world environments.

The paper is organised as follows. A review of related literature is provided in the following section. The haptic interaction model is described followed by describing the four haptic prototypes and the data models used. The paper closes with the key outcomes from the paper and a discussion of the future direction of this research.

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RELATED RESEARCH WORK

Moving away from the traditional use of visual cues for navigation, a backpack mounted AudioGPS providing audio feedback to the user to help in navigation is presented by the authors in Holland et al [22]. The drawback with such an application is the need for the user to have their sense of hearing fully involved to understand the feedback along with the requirement to carry the backpack mounted application. Hoggan and Brewster [21] comment that possibilities offered by integration of various sensors on a smartphone makes it possible to develop simple, but effective, communication techniques on a device as commonplace as the mobile phone. Heikkinen et al [19] remarks that "the human sense of touch is highly spatial and by its nature tactile sense depends on the physical contact to an object or its surroundings". Robinson et al [38] show that pedestrian navigation using bearing-based haptic feedback can be used to guide users toward their destination using vibration feedback. Human touch is also important in human communication as it conveys non-verbal information [19]. Consequently haptic-feedback has been used successfully for navigation assistance to visually impaired users [3, 27]. Zelek [43] developed tactile gloves to augment "the white cane and guide dog" approach to navigational assistance to the visually impaired. Lin et al [30] demonstrate one of the first use of tactons (structured vibrotactile messages) to encode pedestrian navigation information. More recently, Pielot et al [37] describe PocketNavigator, an Android application, which uses haptics to provide pedestrian navigational assistance. They use haptics "continuously" at every decision point on the path by implementing the tacton framework to encode information for tactile stimulus. Jacobson [25] provides a good overview of the accessibility and usability issues of representing spatial information through multimodal interfaces via visual, audio and haptics modes. Elliot et al [9] warns that "when combining tactile and visual display, global awareness should be supported through the visual modality and local guidance through the tactile channel." Sahami et al [39] assesses the potential of tactile notifications on mobile devices. They conclude that "by varying the intensity and pattern of the vibration information can be reliably communicated". Pedestrian navigation in complex environments without assistance is difficult. Hartley et al [17] remarks that "using only cognitive map representations when following routes should not impair accuracy but might increase the demand for perceptual processing and adversely affect speed of travel". Over-reliance of mobile navigation systems may cause to user to not develop the spatial knowledge that may be required when automation fails. Parush et al [35] remark that users should not be always forced to follow automatic navigation systems but instead be more active in the wayfinding task in order to gain better spatial knowledge. Consequently a system that includes haptics could help users interacts more with their environment and less with the mobile device. Lee and Starner [29] present two experiments to evaluate wrist-worn wearable tactile displays (WTDs) that provide easy to perceive alerts for "on-the-go users". Their results indicate that when visually distracted users' reactions to incoming alerts become slower for the mobile phone but not for the WTD. Srikulwong and O'Neill [40] investigate using haptics to alert users about landmarks in a town or city. With training, participants were able to haptic signals for distinguish landmarks from directional signals and recognized over 80% of learned landmarks. They also found that participants did not show high rates of "forgetting" the haptic signals they had learned. Amemiya et al [1] develop a novel handheld kinesthetic force-feedback device is based on the characteristics of human perception. It convey a sense of pulling or pushing the user towards a specific landmark or object and can be used to alert users that they are "near" a specific POI. *Tactile Wayfinder*, as described by Pielot and Boll [36], uses a tactile torso display to present the directions of a route. The device is a torso-based eight tactor belt that is used to provide direction information. While *Tactile Wayfinder* has its advantages it was unable to keep synchronised with the navigational system. Pielot and Boll [36] summarise their findings by concluding that rather than replacing audio-visual interaction with haptics the *Tactile Wayfinder* [36] is intended to combine the advantages of the low interaction tactile display with superior performance of the audio-visual system. Klippel et al [26] argue that turn-by-turn direction instructions are often too detailed leading to cognitive overload or unnecessarily complex. Robinson et al provides distance and orientation information to the user via vibrations with varying pattern and frequency. Asif et al [5] extend this concept to automobile drivers. The driver perceives countable vibrotactile pulses, which indicate the distance in turn by turn instructions. They found that the approach is a simple way of encoding complex navigational information. May et al [31] indicate that landmarks were by far the most predominant navigation cue and these should be included in directions. The authors found that distance information and street names were infrequently used. Additional information such as landmarks is used to enable navigation decisions but also to enhance the pedestrian's confidence and trust. As smartphones continue their technological evolution more sensors will be integrated into the mobile hardware such as noise sensors [11] or air quality sensors [41]. As the results from the study carried out by Heikkinen et al [18] concludes users see haptic-feedback as a compliment to the existing modalities rather than it being a "stand alone" modality.

HAPTIC INTERACTION MODEL

This paper (and in greater detail the full workshop paper) describes the development of four applications which use haptics to provide navigational assistance to pedestrian without requiring the user to constantly interact with the mobile device. The Android-based mobile device used for testing comes equipped with a GPS receiver, digital compass, and accelerometer. The application prototypes uses the Cloudmade Routing API [7] for pedestrian route planning using the OpenStreetMap database. Visual feedback is provided to the mobile device for instances where the user chooses to look into the phone. The user can hold the phone discretely in their hand or leave the phone in their pocket. The GPS traces of users can be logged in a PostGIS database to assist in the analysis of user behaviour along planned routes. The only explicit interaction is when the user initially specifies their destination location. The HapticGPS and/or HapticCompass prototypes can be used in any location which has

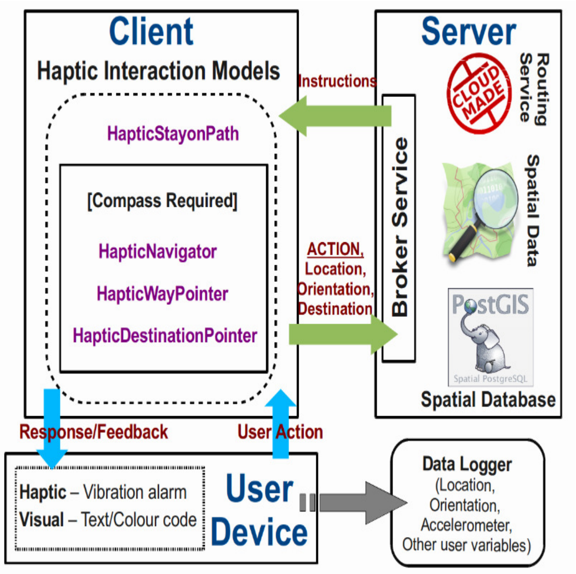

Figure 1. The Haptic Interaction Model

road and street network representations in the global OpenStreetMap database.

The overall haptic-interaction model is illustrated in Figure 1 and consists of of three main components: client, server, and the user/device. The data logger module is used to capture data for research purposes only. PostGIS is used to store all the spatial data. The Haptic Interaction Model works based on inputs (actions/movements) from the user and also the results from the server based on the sensor values from the phone. The model provides dual feedback: as haptic feedback in the form of vibrations and as visual feedback using textual description and colour coded buttons. Section *Application Prototypes* will now explain the model in Figure 1 in more detail and outline the four implementations.

APPLICATION PROTOTYPES

While map-based mobile navigation systems are popular we feel there is research, and commercial scope, for alternative modalities such as haptics particularly in busy and crowded urban environments. Haptics ensure the user's attention is better utilised on the dynamic environment around them and to a lesser extent on the mobile device sceen. The four application prototypes are as follows. Section *HapticStayonPath* describes "HapticStayonPath" which uses only the location information of the user. Section *HapticNavigator* introduces "HapticNavigator" which provides users with information about general walking direction to the next waypoint using haptic feedback. Then section *HapticWaypointer* describes "HapticWayPointer" only partially assists user navigate while the final prototype is described in section *HapticDestinationPointer*. "HapticDestinationPointer" does not provide any information on the shortest path but provides the user with haptic feedback when pointing in the direction of the destination. In all four prototypes information is also presented in the form of color coded buttons and textual description incase the user is confused with the haptic feedback at any stage or if battery consumption becomes an issue. Table 1 summarises the four prototypes based on feedback type and the sensor/battery usage. Table 1 also allows a quick comparision of the features of each prototypes described in Section *HapticStayonPath*.

HapticStayonPath

The "HapticStayonPath" is a prototype which uses only the current location of the user to guide them on the route. By modulating the frequency of the vibration alarm we are able to convey messages of distance and direction to the user. The use of repeated high frequency vibration is used to convey that the user is moving away from the desired shortest path. Small pulses of shorter duration were provided repeatedly in certain intervals to inform the user that they are on the correct path. Using the GPS readings of the moving user the bearing is calculated and feedback can be provided for additional scenarios such as when the user appears to be starting to diverge off the shortest path and take a different direction. The "HapticStayonPath" prototype described in algorithm 1, could be used as a simple navigation aid for visually impaired pedestrians or users trekking/hiking and must follow a predefined route. In hiking/trekking situations it is sometimes impossible to find easily identifiable landmarks making "HapticStayonPath" a very suitable candidate for use. The following subsections define prototypes which are categorised under "HapticCompass" as they utilise the current orientation along with the location of the user/mobile device.

HapticNavigator

"HapticNavigator" is a waypoint-to-waypoint navigation assitance system which provides users with information about general walking direction to the next waypoint using haptic feedback. A waypoint is defined as a node in the path where the user must change the direction of movement, such as an intersection. Typically users would view the map (paper or digital) and then try to re-orientate themselves in the direction of movement by comparing the buildings or landmarks represented on the map to the features they see around them. Using "HapticNavigator", as decribed in algorithm 2, the user *scans* the area by holding the phone horizontally and slowly moving along the horizontal plane. This is depicted in Figure 2 on top of a map layer from OpenStreetMap. When the user is pointing in the direction of the next waypoint they will are alerted by haptic feedback. The user repeats this action at waypoints until they reach their destination. The "HapticNavigator" could potentially be used for users "in a hurry".

HapticWayPointer

The "HapticWayPointer" is a prototype designed to partially help the user navigate as described in algorithm 3. This allows the user to "explore or wander" along the route. At any location the user selects their destination and they are alerted when they are pointing (via scanning - see Section *HapticNavigator*) in the correct direction of the shortest path to their destination. After being instructed as to the initial direction of movement it is the user's responsibility to request

```
Data: The input current user location $s$ and destination
        location $e$. $\alpha$ is a buffer size in meters.
Call Cloudmade Routing Service to obtain shortest path
between $s$ and $e$;
Download XML-encoded result from Cloudmade;
Parse and store route in database;
begin
    $d \longleftarrow setLineStringBufferSize(\alpha)$;
    $v \longleftarrow getRouteLineString()$;
    $U \longleftarrow getCurrentUserLocation()$;
    while $(U.location \neq buffer(e, d))$ do
        $U \longleftarrow getCurrentUserLocation()$;
        $x \longleftarrow getDistanceToLineString()$;
        if $(U.location = buffer(v, d))$ then
            Vibrate small frequency pulse;
            Display green button;
            Display distance to destination $e$;
        else
            if $((x > d)$ and $(x < 2d))$ then
                Vibrate Medium frequency pulse indicating
                user moving away from optimal path;
                Display orange button;
            end
            if $(x > 2d)$ then
                Vibrate Very high frequency pulse
                indicating user is now $\geq 2\alpha$ from optimal
                path;
                Display red button;
            end
            Display distance to destination $e$;
        end
    end
end
```

Algorithm 1: Algorithm HapticStayOnPath

```
Data: The input start location $s$ and the destination location
        $e$. $\alpha$ is a buffer size in meters.
Call Cloudmade Routing Service to obtain shortest path
between $s$ and $e$;
Download XML-encoded result from Cloudmade;
Parse and store route $W = p_1, p_2, ..., p_n$ in database;
begin
    $d \longleftarrow setBufferSize(\alpha)$;
    $n \longleftarrow getTotalNumberOfWaypoints()$;
    $p \longleftarrow setInitialWaypoint(1)$;
    if $(U.location = buffer(e, d))$ then
        User is within $d$ of $e$;
        Display green button;
        Vibrate to alert user;
    else
        while $(U.location \neq buffer(e, d))$ do
            Display red button;
            Display distance to the next waypoint $W_i$;
            while $(p \neq end(W))$ do
                if $(U.distance = buffer(p, d))$ then
                    Vibrate indicating user has reached a
                    waypoint $W_i$;
                    Display orange button;
                    repeat
                        User is now pointing towards the
                        next waypoint $W_i$;
                        if
                        $(U.direction = direction(W_{i+1})$
                        then
                            Vibrate indicating user pointing
                            towards next waypoint $W_{i+1}$;
                            Display green button;
                            Display distance to the next
                            waypoint $W_{i+1}$;
                        end
                    until $(Scan() = true)$;
                    User walks in the direction of the
                    vibration alert;
                    $p \longleftarrow getNextWaypoint()$;
                    $U \longleftarrow getCurrentUserLocation()$;
                end
            end
        end
    end
end
```

Algorithm 2: Algorithm HapticNavigator

Figure 2. At a waypoint the user scans the area for information

feedback along their route. The user can divert off route as they please and are not forced to follow a shortest path.

HapticDestinationPointer

The "HapticDestinationPointer" prototype (Algorithm 4), like "HapticWayPointer", does not provide any information on the shortest path to the destination. It provides users with haptic feedback when pointing in the direction of the destination. Distance-to-destination is also encoded into the haptic feedback. When the user scans (see Section *HapticNavigator*) they are provided with information about the straightline distance to their destination. This is similiar to work by Robinson et al [38] who feel that users should have opportunities to "explore place while trying to get to their destination". Haptic feedback provides the direction to destination and the straightline distance to the destination information.

As shown in Table 1 the four prototypes have different requirements in regards to the complexity and functionality of the underlying algorithms. The prototypes also vary in regards to the types of haptic feedback, Internet connection requirements and battery usage. Figure 3 represents the prototypes and how they differ from each other. As we move from west to east in Figure 3 we see the representation of increase in two factors - "System Complexity and functionality and Internet Connectivity". From south to north we seeing increase of "Battery Usage and amount of Haptic Feedback" represented in figure 3. Providing continuous haptic feedback to the user will result in highest battery as is the case with "HapticStayonPath". This also requires an Internet connection at all times. "HapticNavigator" is a waypoint by waypoint navigation prototype which needs GPS readings and Internet connectivity at all times. Haptic feedback is only moderately required for "HapticNavigator" as it is only at waypoints that the user is provided with haptic feedback. Consequently battery usage is not overly burdensome. Haptic feedback and Internet usage in case of "HapticWay-

```
Data: The input current user location $s$ and destination
      location $e$. $\alpha$ is a buffer size in meters
User Requests for Direction to next Waypoint;
Call Cloudmade Service;
Download XML-encoded result: parse and store waypoints;
begin
    $d \longleftarrow setRoutePointBufferSize(\alpha)$;
    $U \longleftarrow getCurrentUserLocation()$;
    $D \longleftarrow getLocationOfNextRoutePoint()$;
    if $(U.location = buffer(d, e))$ then
        User is now within $\alpha$ of destination $e$;
        Display green button;
        Vibrate to alert user of $e$;
    else
        while $(U.location \neq buffer(e, d))$ do
            repeat
                Until user points their mobile device in the
                correct direction;
                if $(U.direction = D)$ then
                    Display orange button;
                    Vibrate;
                    User moved in direction of the
                    waypoint;
                    Turn GPS off;
                end
            until $(Scan() = true)$;
            $U \longleftarrow getCurrentUserLocation()$;
        end
    end
end
```

Algorithm 3: Algorithm HapticWayPointer

Table 1. This table contains a summary of the four haptic prototypes for pedestrian navigation discussed in the paper. The table outlines if haptic feedback is used, if text and/or colour is used to convey information, compass, GPS, and battery usage. The Internet connectivity requirements of the prototypes are also outlined.

	HapticStayonPath	HapticNavigator	HapticWayPointer	HapticDestinationPointer
Haptic feedback	Yes	Yes	Yes	Yes
Text/colour code	Yes	Yes	Yes	Yes
Compass usage	No	Yes	Yes	Yes
GPS 'always' on	Yes	Yes	No	No
Internet usage	High	High	Low	Low
Battery usage	High	Medium	Low	Low

```
Data: The input current user location $s$ and destination
      location $e$. $\alpha$ is a buffer size in meters. $W$ represents
      walk limit - where it represents a long distance to
      walk until destination $e$

User Requests for Direction to Destination;
Calculate distance and direction to destination;

begin
    $d \longleftarrow setRoutePointBufferSize(\alpha)$;
    $U \longleftarrow getCurrentUserLocation()$;
    $D \longleftarrow getDistanceToDestination()$;
    Set $W$ to appropriate value - for example 800m;
    if $(U.location = buffer(e, d))$ then
        User is within $\alpha$ of $e$;
        Display green button;
        Vibrate to alert user;
    else
        while $(U.location \neq buffer(e, d))$ do
            repeat
                Until user points their mobile device in
                correct direction;
                if $(U.direction = direction(e))$ then
                    if $(U.distance > W)$ then
                        Display orange button;
                        Display straightline distance to $e$;
                        Vibrate to indicate distance $> W$;
                    end
                    if $(U.distance > \alpha)$ then
                        Display orange button;
                        Display straightline distance to $e$;
                        Vibrate to indicate distance $> \alpha$;
                    end
                    User follows their own path to
                    destination;
                    Turn GPS off;
                end
            until $(Scan() = true)$;
            $U \longleftarrow getCurrentUserLocation()$;
        end
    end
end
```

Algorithm 4: Algorithm HapticDestinationPointer

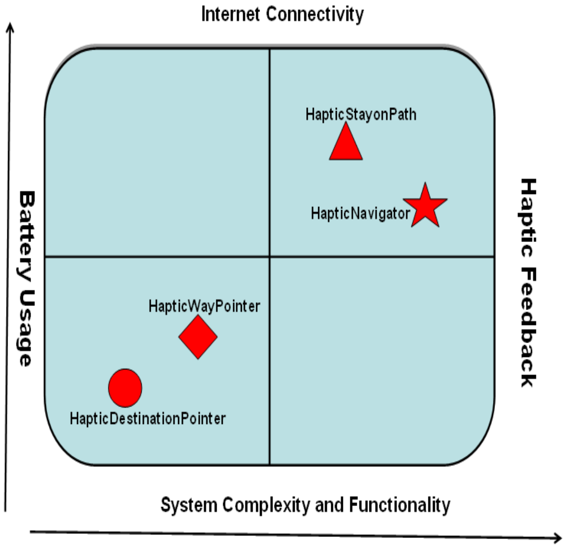

Figure 3. The four haptic feedback prototypes are shown. System complexity and functionality increase along the X-axis direction (as does requirement for Internet connectivity. Battery usage increases along the y-axis

Pointer" and "HapticDestinationPointer" is minimal as the user must explicitly request assistance during their travel. Consequently, the user themselves are in control of the number of requests.

DATA AND CONNECTION ISSUES

The four prototypes discussed in this paper are inherently spatial data driven. The availability and accuracy of spatial data is important for these application to work efficiently, effectively, and correctly. OpenStreetMap (OSM) is a collaborative project to create a free editable map of the world. Volunteers or common citizens created these maps using data from portable GPS devices, aerial photography, and most importantly from local knowledge of the area. OSM coverage is not uniform across all places and usually very well mapped are mostly concentrated within cities and towns [20]. The lack of spatial data in a particular region can lead to these systems not performing well. The popularity of OSM is growing quickly and the diversity and quantity of the points of interest provided offer new opportunities and challenges in creating customized and detailed visualization of cities [33]. The systems are developed to use OSM but could switch to an alternative source of spatial data if required. The OSM option allows us to integrate external web-services (Cloudmade) for pedestrian route calculation using OSM data. We believe this option provides us with a better overall spatial data management structure. As several studies have shown (see Girres [14], Haklay et al [16] or Haklay [15]) OSM data is comparable in quality and geometric accuracy to that of traditional mapping products such as those produced by National Mapping Agencies and commerical mapping vendors. OSM data also includes many geographical features that are not available in other spatial datasets. For example for blind or visually impaired pedestrians many cities in OSM have the location of tactile pavements, assisted traffic signals, etc mapped accurately.

An Internet connection is another requirement for the systems outlined in this paper. The mobile device running these applications must be connected to the Internet. While "HapticWayPointer" and "HapticDestinationPointer" require limited internet access and connects only when the user requests for feedback and it is then switched off. "HapticStayonPath" and "HapticNavigator", on the other hand, both require continuous Internet access. In future we shall look to develop these applications that can work "offline" most times. Such extended versions of the applications will only require Internet access initially to set the required system variables for the applications. OSM data, for example, could also be stored directly on the mobile device storage space. "HapticStayonPath" requires Internet access throughout and provides haptic feedback continuously to the user until they have reached the destination. As the position of the user must be continuously updated the GPS is turned on constanly also. These factors combined lead to heavy battery usage and would not be a practical option on very long routes. These issues are summarised in the illustration in Figure 3 which shows the requirements for battery usage and Internet connectivity against overall system complexity and functionality. As stated previous table 1 provides a similar type of overview. In the next section we provide some closing discussions and some conclusions from this work.

DISCUSSIONS AND CONCLUSIONS

There are a number of important outcomes from the integration of haptics as a modality for navigation assistance on mobile devices. These are summarised as follows: there is a reduction in the attention requirements of the user to the mobile device screen; haptic communications have no language/cultural barrier; decision making appears to be made quicker, when the haptic system is learned by the user; and there is an overall reduction in the cognitive burden on the user. We shall now elaborate briefly on each of these four issues.

- Haptic feedback allows navigational information be provided without requiring the user to pay strict attention to the mobile screen. This ensures that the user is attentive to their activity at that time [12]. Similiar to voice feedback on Sat Nav systems in cars (to allow drivers focus on the road) haptics ensures that the use does not have to allocate all of their attention to other tasks such as working with the user interface. As stated above the pedestrian may be involved in activities (carrying shopping, walking with friends) where it may be unsuitable to have a visual guidance system.
- Unlike map displays and voice communication the sense of touch does not have any language barrier [32]. Thus, such a system can be consumed by a global audience regardless of the user's native or spoken languages. This greatly reduces the software development for the applications where multilingual issues must be addressed. Mapping and voice feedback applications must very carefully deliver information in different languages.
- Haptic feedback ensures decision making regarding the navigation task occurs quicker than compared to decision making using a purely visual interface or where the user must orient themselves in the correct direction [2, 34, 38]. Haptic feedback ensures quicker user response time. Users also re-orientate themselves quicker at complex intersections or junctions.
- Finally, it has been shown that haptic feedback reduces the cognitive burden on the user [6]. Haptics reduces the requirement for the user to orientate and re-orientate themselves based on the mobile display by comparing the features displayed on the map to the real world features around them. However, an interesting point commented upon by Parush et al [35] is that while haptics is certainly a very useful and exciting modality if users become dependant on haptics then this could lead to a degradation in overall spatial and navigational knowledge and ability.

Traditional pedestrian navigation systems use visual interfaces (digital maps, textual descriptions, images, etc). Audio-based navigation is another common modality. Haptic-based feedback is gaining interest within the research community and there are now a growing list of applications [34]. Integrating haptics into pedestrian navigation systems provides an environment where the user is not continuously interacting with the visual interface of the mobile device and can follow a "heads-up" [38] approach to route following. Feedback from the user trials was very positive overall. From a qualitative viewpoint some of the user responses were as follows: "These applications do not require me to know much about maps and map symbols and about orienting myself to the correct path" and "the subtle feedback ensure that I don't have to be overly attentive to my phone during my walk". Since "HapticStayonPath" does not use the compass it was difficult for users to orientate themselves at complex junctions and intersections. "HapticNavigator" helps users get to their destination in the shortest time. As the vibration alarm is only used at waypoints battery energy is conserved. In user trials "HapticWayPointer" and "HapticDestinationPointer" provided users with better control over their route choice. Quantitativ results showed that most users do not take the shortest path but follow a meandering route to their destination.

This paper has introduced a haptic interaction model for mobile-based pedestrian navigation applications. We feel there is great potential for haptic-enabled navigation applications as an alternative to purely visual or audio-based feedback applications. Haptics is an unobtrusive feedback mechanism and this allows the user interacts more with their physical environment. The "scanning" action (refer to Figure 2), by holding the phone horizontally to query about direction, distance, or orientation information, ensures that quick responses are obtained by the user. Our user trials show that waiting time at waypoints is reduced. It is intended that this research will extend to using haptic feedback interaction for pedestrian navigation indoors in the absence of GPS signals. Paths and lines in OpenStreetMap can be tagged specifically as indoor routes and subsequently OSM routing engines such as Cloudmade [7] can plan routes indoors. Ensuring that the spatial data in OpenStreetMap is semantically rich and spatio-temporally correct is also of critical importance to the approaches outlined in this paper. A serious challenge for application development in this area concerns the positioning techniques. Especially in urban environments, due to obstruction effects, the achievable accuracy of conventional GPS systems does not seem to fulfil the requirements for all pedestrian navigation applications [4]. This is also a problem in rural and country areas[13]. However, more and more citizens are using their "smartphones" for every day tasks and consequently are much more likely to embrace new technologies such as haptics for these tasks. It is an exciting time for mobile application technologies and development.

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