Integrating Haptic Feedback to Pedestrian Navigation Applications

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ABSTRACT
The development of a haptic-feedback enabled mobile application for pedestrian routing is described. One of the challenges presented to users of pedestrian navigation applications on mobile devices is the requirement that the user continuously interacts with the visual interface on the mobile device. Haptic feedback or haptics, is a technology that uses forced feedback, vibrations and/or motions to the user which are interpreted using our sense of touch. The haptic user interface, in our application, on a mobile device provides unobtrusive feedback in the form of vibration alarms to assist the user in navigating from one point to the other. The user can hold the mobile device discretely in their hand without the need to view the screen. For spatial data the OpenStreetMap (OSM) database is used while the Cloudmade routing API is used as the routing engine.

KEYWORDS: Haptics, pedestrian navigation, paths, spatial data

1. Introduction

Haptic-feedback or haptics is a technology that provides forced feedback, vibrations, and/or motions in hand held devices. Haptics is one of the interface modalities which are available to both impaired and non-visually impaired pedestrians. A very well known example of haptics technology is the Nintendo Wii controller. Through the use of accelerometers, the Nintendo Wii controller is able to generate vibrational feedback to the user. While the feedback is not necessarily "realistic", the popularity of the Wii clearly shows that there is a demand for greater, unrestrained interaction between a user and a (virtual) environment. The sense of touch is an integral part of our sensory system we use extensively when interacting with the environment and people. It guides our motor system, provides unique information or replaces other senses when they cannot be used. Touch is also important in communication as it can convey non-verbal information (Heikkinen et al.; 2009). The rapid advances in smart phone technology has allowed developers begin using Haptic feedback on mobile devices. The HTC smart phone has many sensors including: vibration, accelerometer, compass, GPS. All of these sensors can be controlled using the Android Smart Phone API. In this paper we describe the development of a pedestrian navigation application for Android-based smart phones. Our application uses the phone's inbuilt compass and GPS to navigate the user. Feedback is given in "haptic" form through a series of easy to interpret vibrations of the device. The user is not required to use a "neck down approach" and constantly look at the screen of the device. Before we describe the application in more detail we provide an overview of related work in the literature.

2. Literature Review

In our paper Jacob et al. (2010) we provided a detailed literature review of haptic technology. However we concluded that the GIS community had not yet taken full advantage of haptics as a means of user interaction. Jeong (2001) demonstrated that positive results for haptic and auditory display experiments for users in augmenting visually dominant geographical information systems (GIS). This was followed by Jeong and Gluck (2003) where for a given set of GIS tasks (map reading, feature identification, etc) results showed that haptic displays “produce faster and more accurate performance than auditory displays”. The authors comment that in “terms of user satisfaction, the participants preferred the combined display even though they performed best with the haptic display”. Haptics is not new. In Birchard (1999) the “development of computer software for displaying results” for haptics is indicated as one of the three “key strands for haptics research”. One of the problems, before smart phones provided haptic feedback possibilities, in the past was that devices for haptic technology were cumbersome. For example in Zelek (2005) a portable system consisting of a stereo camera and haptic glove was developed and tested. The glove consisted of a collection of tiny vibrating pager motors. In Amemiya and Sugiyama (2009) a handheld device is proposed. The device is rather cumbersome and must be held in both hands. The motors also contribute to noise which draws attention to the user in city environments.

As shown by Ishikawa et al. (2008) having GPS or smart phone assistance is not necessarily the immediate replacement for traditional map-based navigation. Results showed that GPS users traveled longer distances and made more stops during the walk than map users and direct experience participants. Also, GPS users traveled more slowly, and made larger direction error. As commented by Pielot et al. (2009) paper maps are a proven means for navigating in unfamiliar environments, however, they do not prevent people from getting lost or taking unwanted detours. The authors argue that “interpreting the map’s geocentric content is prone to errors”. In the work by Schildbach and Rukzio (2010) the authors show that user performance of map reading (and text reading) on mobile phones “decreases while cognitive load increases significantly” when the users are walking. As stated by Heikkinen et al. (2009) our human “sense of touch is highly spatial by its nature tactile sense depends on the physical contact to an object or its surroundings”. In Pielot et al. (2010a) a wrist-mounted display is developed to deliver a reduced set of navigation information (direction, distance to next decision point and street name). A vibration motor sewn into the watchstrap is used to alert the user when reaching a decision point The results show that Natch users made less navigation errors, felt less visible, and were less distracted by the device. However the commercial viability of Natch is questionable. *PocketNavigator* is developed by Pielot et al. (2010b) uses the compass on a smart phone so that the user can “point at” the next waypoint because direction and distance are encoded in vibration patterns. Preliminary results from a field study show that pedestrians can effectively use this Tactile Compass to reach a destination without turn-by-turn instructions. However the user must *learn* a complex set of pulses. Our short review here shows that results for haptics in pedestrian navigation are beginning to appear. However there are no examples in the literature, to our knowledge at present, where mobile haptic technology, web-service based routing algorithms, and volunteered geographic information (VGI) have been combined to create a pedestrian navigation application. We describe our application in the next section.

3. Application configuration and user trials

OpenStreetMap (OSM) is used as the spatial data source. Our case study area is our university town in Maynooth, Ireland. Our application works as follows and illustrated in Figure 1. Using their Android-based smart phone the user accesses our web application and is presented with a map (or list of popular locations) and they pick their destination (using their current location as their start point). The application then accesses the Cloudmade API to compute the shortest pedestrian route to the chosen destination. An XML file is returned from Cloudmade containing the route waypoints. This XML is then parsed and stored in a spatial table in our local PostGIS database. Our database also has an up-to-date copy of OSM for Ireland stored. A web service, written in PHP, manages all communications between the client application on the phone and the server database. The user holds the mobile device out and scans the area. When the phone is pointing in the correct direction it transmits a vibration for 2 seconds. The user can proceed on their route in this direction. A second distinct vibration is given when the user enters the circular buffer around a waypoint on their route. If there is a decision involved (several exit paths from the way point) then the user again scans with their phone. The phone vibrates for the correction direction. This process is repeated until the user has reached their destination. At all times the location of the user on the route is sent from the mobile device to our server. If the user prefers they can turn the vibration alarm off completely. To supplement the vibration alarm a simple “traffic light” display is shown on the phone. This can be used to conserve battery power on the phone or if the user prefers not to use the vibration alert feature. The display operates as follows: orange button (pointing in the correct direction), red button (the user must scan the area for the correct direction), and green button (everything is OK - the user is within a 10 meter buffer of the planned route). The internal compass in the phone is sensed using the Android API in Java. The two distinct vibration patterns are created in the Java code and can be changed if required. he Android SDK provides the tools and APIs necessary for developing applications on the Android platform using the Java programming language. By providing an open development platform, Android offers functionality to build extremely rich and innovative applications. The SDK provides easy programmatic access to mobile device hardware, GPS, execution of background services, and access to sensors. The application architecture is designed to simplify the reuse of components.

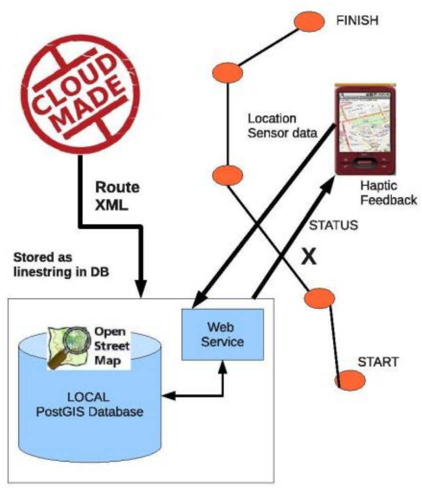

Figure 1: A schematic of the components in our pedestrian navigation application

3.1. User Trials

We have conducted a series of user trials to test the potential use of our application. To eliminate any bias introduced in route selection a start point and destination point were chosen in advance. A smart phone with our application installed was then handed to the user. Five users, who have never worked with HCI related projects, were selected for the trials. They were briefed individually at the start of the trial. This included a description of the feedback mechanism of the device. A short “dummy” route was prepared so that the user could “feel” the different types of vibration feedback presented. Discussion and demonstration was limited to 5 minutes. In case of doubt regarding the haptic feedback during a route following exercise the user could visually check the color coded display on the mobile device. Immediately after completing the individual tasks the users were interviewed for comments and feedback about the use of the device after they completed the journey. As a means of passive data collection and to assist in analysis of the users performance the following variables were recorded automatically by our application: Position of the user at every 1 second in their journey, distance of the current user location to the nearest point on the actual route linestring,the navigational bearing of the user at each point in his path, the speed of the device above the earth's surface at this point, and the timestamp. The compare the performance of those using our mobile application one of our research team familiar with all routes walked these routes using the mobile application for data capture purposes.

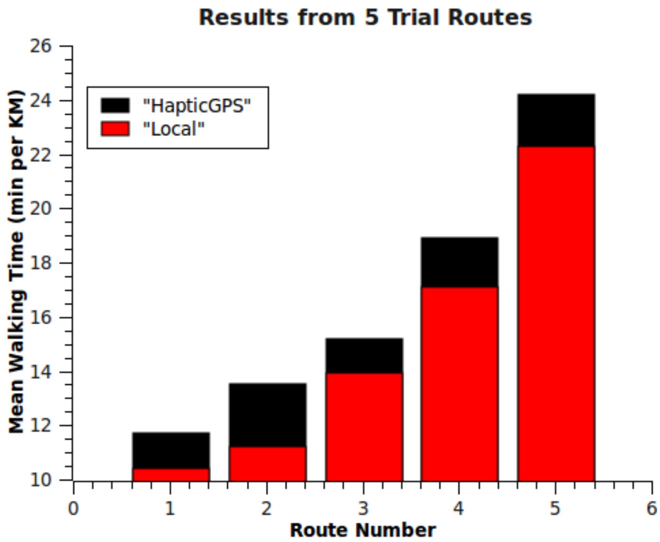

Figure 2: Results from 5 trial routes

In Figure 2 the results of the user trials are provided where the mean walking time in minutes for each route is shown. There are some interesting observations. On all five routes the local pedestrian is faster than the mean overall time for the five users involved in the trial using our application. This result was expected as the users were strangers to the environment where the trials took place and had no previous experience using the application. The local user had no need to pause at critical waypoints as they knew the route. They also had no need to correct themselves based on application feedback. We attempted to maintain equal route complexity for the five test routes. We avoided routes which included steep hills or walking over rough unpaved surfaces. Route 2 contains the largest difference between mean walking time with our application and the local user. The complexity of Route 2 in regard to the number of critical waypoints may be a contributing factor here. Another issue for longer routes (4 and 5) is that users tend to slow down a little depending on their physical fitness over a longer walking route. From the post user trial interviews there was also some interesting feedback. User 4: "I liked this application as it did not need me to know how to use a map on the mobile phone". User 5: "I did not look into the screen of the phone even once during the entire trip, and with so many people around on the path, it was useful as I was always moving and very rarely was standing still". One user responded in relation to the decision making required at the critical points in the routes. User 3: "If I was at a position in the route where there were many choices I got a little frustrated if I was receiving negative feedback from the phone". User 5: "I would only use the application in places where I was a complete stranger as I am likely to take random shortcuts upon routes that I am very familiar with". Some of the users remarked that they often exhibited wayfinding and route following behaviour which caused them to "cut corners" or if the environmental conditions permitted to walk across open areas such as green spaces.

4. Conclusions and Future Work

Overall we are pleased with the first set of user trials of our application. As stated above it is the first example of integrating VGI, web service-based routing, and haptic-feedback on smart phones. From a user interaction perspective the application removes the need for a "neck down" approach to pedestrian wayfinding. The user can move the mobile device but there is no need to compare the map on the mobile device display and landmarks in the local environment. Our users could only see the traffic light colour scheme visualisation. Potentially there is no need to display a visualisation of a map to the user but further user trials are required before proceeding forward without considering a map display. Our application uses a series of simple vibration patterns. At this stage of the PhD research the development is focused on outdoor navigation but work is ongoing on attempting to provide indoor navigation functionality in the future in a seamless fashion. Future work will also include providing the option to dynamically re-calculate the shortest route. For a variety of reasons the user may require a different route to their initially selected route. The application will provide them with functionality to re-calcuate their route. The application, in its present form, is dependent upon OpenStreetMap (OSM) as its source of spatial data. The Cloudmade API exclusively uses OSM. In our casestudy in Maynooth the spatial richness of OSM is very good. However an issue for concern for wider deployment of our application is in location with sparse or poorly contributed OSM mapping. Another aspect of future work will involve accommodating results from human cognition and behaviour in the area of usability and cognition with respect to hand held devices. There is substantial literature on these topics. Golledge (1998) concludes that cognitive maps play an important role in human wayfinding activities. Applications delivering wayfinding assistance must avoid situations where the user experiences momentary disorientation and the lack of recognition of the immediate surroundings. Raubal (2001) addresses the importance of enough signs at every decision point in a path to help the user navigate to the next waypoint. This is most important in case of emergency support applications where the user needs to get to the nearest exit from that decision point. Raubal tests this concept with an airport model to help the user navigate from the check-in counter to the desired gate without the user using an airport map but using sign boards at various decision making points to help the user navigate.

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6. Biography

Ricky Jacob *is a 2nd year PhD Computer Science student. Dr. Peter Mooney is a research fellow at the Department of Computer Science and he is funded by the Irish Environmental Protection Agency STRIVE programme (grant 2008-FS-DM-14-S4). Dr. Padraig Corcoran is a lecturer and post-doctoral researcher also at the Department of Computer Science NUI Maynooth.* *Research in this paper is carried out as part of the Strategic Research Cluster grant (07/SRC/I1168) funded by Science Foundation Ireland under the National Development Plan. The authors gratefully acknowledge this support.*