MOBILE LOCATION BASED SERVICES: NON-VISUAL FEEDBACK USING HAPTICS

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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 device such as a mobile phone. Historically, human-computer interaction has been visual, text and images on the screen. In this paper, we discuss our Haptic Interaction Model which describes the integration of haptic feedback into Mobile Location Based Services such as knowledge discovery, pedestrian navigation and notification systems. A knowledge discovery system called the *Haptic GeoWand* is a low interaction system that allows users to query geo-tagged data around them by using a point-and-scan technique with their mobile device. *Haptic Pedestrian* is a navigation system for walkers. Four prototypes have been developed classified according to the user's guidance requirements, the user type (based on spatial skills), and overall system complexity. *Haptic Alert* is a notification system that provides spatial information to the users of public transport. In all these systems, haptic feedback is used to convey information about location, orientation, density and distance by use of the vibration alarm with varying frequencies and patterns to help understand the physical environment. User trials have elicited positive response from the users. Haptics integrated into a multi-modal navigation system and other mobile location based services provides more usable, less distracting but more effective interaction than conventional systems.

KEYWORDS

Haptics, Location Based Services, User Interfaces, HCI, Mobile.

1 INTRODUCTION

A Mobile Location Based Service (MLBS) can be defined as an information service that uses the current location as one of the contexts for providing useful information to the user. This information therefore will be more pertinent as it will be local to (within a short walking distance) the user's position. To provide a MLBS service, a device needs a method for obtaining an accurate location, a data connection to a service provider and a user-interface allowing the user to interact with the service.

From the late 1990s MLBS has found the interest of researchers and businesses throughout the world. In the early years localisation (finding the physical geographic location) was usually performed using proximity to cellphone towers and the services were not accurate and efficient. With the availability of newer technologies that integrated sensors like accelerometer and magnetometers along with a Global Positioning System (GPS) receiver into light-weight mobile devices, more accurate localisation of the user was possible. Mobile location based services provide services such as on street pedestrian navigation in real-time, city tourist guides, public transport information about bus stop locations and real-time arrival data, and

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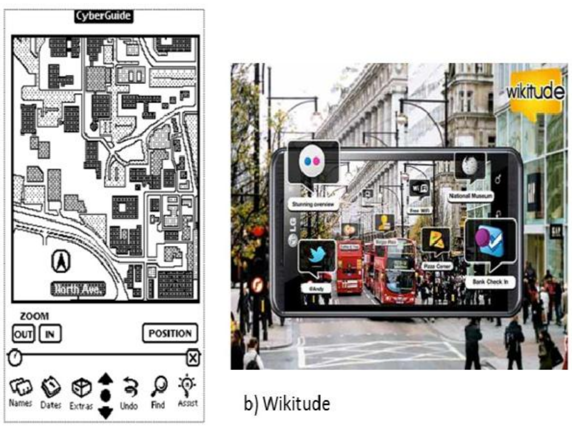
dynamic data like weather conditions and pollution levels at a particular place.

People use mobile location based services for assistance for searching points-of-interest (POI), and also for obtaining navigation assistance to find that place. The various types of data that can be delivered by MLBS are:

- location (current place where the user is/inform the user when they reach a particular place),
- distance (how far it is to the nearest POI/how much more to walk),
- orientation (direction in which the POI/place is located), and
- density (number of features/POIs in their proximity).



b) Wikitude

a) CyberGuide

Figure 1: a) *CyberGuide*, one of the early (1996) prototypes of mobile navigation assistant systems and b) *Wikitude*, one of the latest (2012) augmented reality browsers.

There has been much research into mobile location based services. One of the earliest adaptations of such a mobile guide and navigation assistant tool was CyberGuide [1]. Figure 1a represents the visual interface of the outdoor navigation component of CyberGuide and Figure 1b represents one of the latest augmented reality browsers called Wikitude [30].

2 MOBILE LOCATION BASED SERVICES

Based on the kinds of spatial interaction techniques and information representations, they can be classified into visual or non-visual MLBS.

They are:

1. Mobile Cartography – Maps,

2. Landmark information using geo-tagged photos,

3. Textual description,

4. Mobile augmented reality applications,

5. Audio feedback by speech and non-speech, and

6. Haptic feedback

The most popular interaction methods used in MLBS is the use of overlays of information on maps for navigation assistance and spatial query responses [6, 7, 16, 20, 29]. Some systems provided textual feedback with turn-by-turn directions and some integrated landmark information and photographs [5, 19, 23]. Researchers have also integrated panoramic images or other geo-tagged images of places along with information overlay to provide feedback to the user [2, 9, 28]. We also see a shift from pure location-based to orientation-aware systems with the availability of low cost on-board digital compasses. Thus bearing based mobile spatial interaction has gained popularity [11, 21, 25, 26, 27]. Most recent works show that there is great interest in the use of augmented reality in mobile spatial interaction systems [13, 18, 30]. In augmented reality based systems, the location and orientation of the mobile device is used along with the camera of the device

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to provide spatial information to the user overlaid on real-time images.

Researchers have also looked at the use of non-visual techniques like audio and haptics to provide users with feedback about spatial information. For audio based systems, researchers have looked at both speech based feedback (similar to the GPS devices in car navigation systems) and also non-speech based techniques (using sounds/music by varying frequency and amplitude). One of the early adaptations of using audio feedback was GuideShoes [15]. Here background awareness principles are incorporated into a wearable tangible interface, providing users with information regarding their travel. Loomis et al. developed audio based navigation assistance for visually impaired users [14]. The users were able to navigate using the system along a predefined route. Virtual acoustic display, and verbal commands issued by a synthetic speech display were tested and the virtual acoustic display fared best in terms of both guidance performance and user preferences. Holland et al. used a simple form of non-speech audio and built the AudioGPS prototype [8]. It is an audio user interface for a Global Positioning System (GPS) that is designed to allow mobile computer users to carry out a location task while their eyes, hands or attention are otherwise engaged.

Pielot et al. describe an android smartphone based system called the Pocket Navigator. Here the users can leave the device in the pocket while being guided non-visually through vibration cues [17]. For navigation, distance and direction information to the next waypoint is provided by encoding its direction and distance in vibration patterns. Robinson et al. discusses about the heads-up interaction with mobile devices by integration of multimodal feedback using gestures [22]. The user is alerted about geo-tagged (related to a location) information using a vibration alarm. The user is able to find out what form of information (information in the form of images, text, audio and/or video) is available by performing the gestures.

We can classify mobile location based services into the following broad application types:

- knowledge discovery,
- pedestrian navigation and way finding, and
- notification/alert systems.

3 RESEARCH MOTIVATION

In According to Carroll, Human Computer Interaction (HCI) is “concerned with understanding how people make use of systems that embed computation, and how such systems can be more useful and usable” [3]. Chittaro believes that in order to have users (especially novice ones) enthusiastically adopt mobile computing devices, we will need to prevent the pains and complexities of interacting through very limited input and output facilities [4]. He also adds that mobile services will not be successful if we do not understand mobile users and design for their contexts, which are very different from the ones traditionally studied in HCI. Thus emphasis on the need to keep the end user in the centre of design/development stage for services involving mobile interaction is important.

Most applications providing mobile location based services are designed with the belief that the user will devote their full attention to the interaction. However, in many situations in the real world, the use of mobile spatial interaction is more often than not the secondary task. The primary task, like driving a car or avoiding other pedestrians and obstacles, should not be directly affected while using assistive technologies.

Mobile Spatial Interaction techniques and presentation of such information on mobile terminals with small screen size has always

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been a big challenge. While the benefits of visual interfaces and maps in general can be seen, the need for modeling various other user-related contexts is also important. The need to ensure that the user can also attend to other tasks while on the move and using such location based services is also important. All these factors need to be considered at the system design phase to ensure the optimal usability of such interfaces. Further research is needed to evaluate which type of information presentation is appropriate for which tasks and in what contexts. Despite the ubiquitous nature of visual interfaces, they can be highly distractive.

Effective communication of spatial information to the user in an easy to understand manner is one of the fundamental requirements for any mobile location based service. One of the goals listed by Reichenbacher is taking into account the user's cognition of space; delivering and presenting spatial information in a mode easily perceivable for the user [20].

Any mobile location-based service ideally needs to provide the following:

- the fast, complete, clear delivery of information
- ease of use while mobile or performing other tasks (multitasking)
- non-obtrusive feedback
- have simple interfaces and interaction techniques
- suitable for all physical conditions.

A purely visual interface for interaction with the device would mean a lack of balance in attention distribution between the primary task (walking) and the secondary task (using the device for assistance). On a bright sunny day or during rain/snow, it will not be possible to use the visual interface effectively and thus there is a need to provide low interaction/low-attention non-visual modes of feedback to the user.

Therefore, we propose haptics or using the sense of touch may be an effective way to communicate with the user. The word haptics is derived from the Greek word haptesthai, which means 'of or related to the sense of touch'. In the psychology and neuroscience literature, haptics is the study of human touch sensing, specifically via kinesthetic (force/position) and cutaneous (tactile) receptors, associated with perception and manipulation. Haptics should be able to provide subtle feedback about information such as distance to a particular Point of Interest (POI) or the direction in which the user needs to walk.

4 HAPTIC INTERACTION MODEL

The Haptic Interaction Model described in this paper encompasses the three application types – knowledge discovery, pedestrian navigation and alert/notification systems. The textual input for the interaction model is provided by keyboard input. When someone asks another person for directions to a place, a hand pointing gesture would mean the direction in which they need to head to get to that destination. We thus integrate this feature into our system where the user can query features by performing such pointing and/or scanning gestures without having to look into the mobile device (Figure 2). This provides the orientation information of the mobile device. The GPS receiver provides location information of the device.

Figure 2: The user performing the *scanning* operation.

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Figures 3. illustrates the Haptic Interaction Model which represents the various components within the model that includes the three sub-systems –

- Haptic Geowand,
- Haptic Pedestrian, and
- Haptic Alert

The broker service receives location specific information from the system and provides the response based on the inputs and processing these queries. The output is presented with feedback both in subtle visual form using color coded buttons with red, orange and green representing different information like distance and density. Haptic feedback by the use of varying frequency and pattern of vibration is used through the mobile device to provide eyes-free information to the user by representing location, distance, direction or density information.

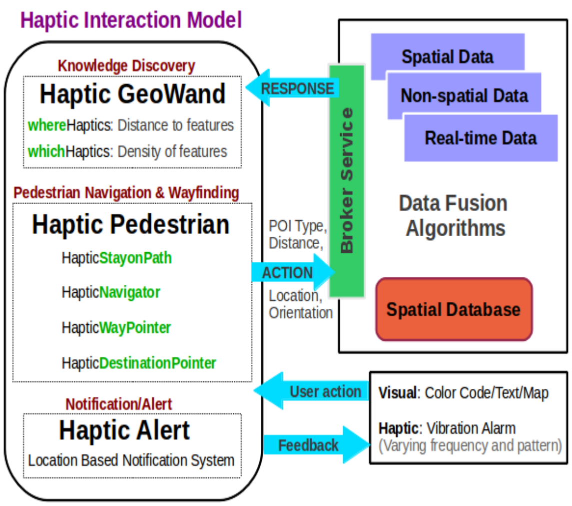

Figure 3: The Haptic Interaction Model for Mobile Location Based Services.

4.1 Haptic GeoWand

The *Haptic GeoWand* is a low interaction system that allows users to query geo-tagged data along a street or around them by using a point-and-scan technique with their mobile device; it provides information using haptic feedback [11]. Here the orientation of the user (mobile device) along with the location information and selected POI are used as inputs to the haptics enabled system. Thus, this is a combination of the pointing gesture based queries with haptic feedback to represent the results. Along with the textual description of available near-by objects in the direction the user is pointing, haptic feedback in the form of vibration alarm with varying frequencies and patterns is used. The feedback is provided using haptic feedback to reduce the cognitive burden on the user by delivering quantitative information about the distance/density to interested feature type using variations in vibration frequencies.

Information regarding the distance(s) to features is provided by the *whereHaptics* module of the system. Here haptic feedback is used to inform the user about the zone (near, far, or very far) that the features are available along any particular street. Vibration frequency increases from near to very far with distinctly varying patterns ensuring the user is able to understand the feedback without having to look into the mobile. Information regarding density of feature(s) along a street is provided by the *whichHaptics* module of the system. Varying frequency and patterns of vibration are used to inform the user about the density of features/POIs along any given path. This enables the user to check which street he/she should take when they have multiple choices of a particular feature(s) available to them.

Haptic GeoWand based pointing and scanning to query for location of interest and obtaining feedback in the form of haptic feedback is stage one where the user looks for information. Once the user queries and finds POIs or destination where they need to go to, the user would like to be presented with information to provide navigation assistance to get to that particular POI/destination. In the following section we look at how pedestrian navigation information can be provided using haptic feedback.

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4.2 Haptic Pedestrian

While location information is useful in helping to provide navigation assistance, the availability of bearing and heading information can ensure more useful data with respect to user movement. The availability of information like bearing and heading can help enhance the service provided to the user. *Haptic Pedestrian* includes four different user interaction models for pedestrian navigation using haptic feedback [10]. Here the users can query for spatial information by performing the scanning operation by pointing gestures with the mobile device (Figure 2). By varying the vibration frequency and pattern different distance information along with directional information is provided. The pedestrian navigation prototypes considered various ways in which the user could be provided with navigation assistance based on various methods like:

1. Hot and cold technique (*Haptic StayOnPath*),
2. optimal path waypoint-by-waypoint navigation method (*Haptic Navigator*),
3. general shortest path heading method (*Haptic Waypointer*), and
4. navigation via direction information about general heading towards the destination (*Haptic DestinationPointer*).

The *Haptic StayOnPath* is a prototype which uses only the current location of the user to guide them along a pre-calculated route. By modulating the frequency of the vibration alarm we are able to convey messages about deviation from the shortest path to the user.

The *Haptic Navigator* is a waypoint-to-waypoint navigation assistance system which provides users with information about general walking direction to the next waypoint using haptic feedback and simple visual cues. A *waypoint* here is defined as a node in the path where the user must change the direction of movement, such as an intersection.

The *Haptic WayPointer* is a prototype designed to help the user navigate where the user is allowed to "explore or wander" along the route. At any location the user selects their destination and they are alerted when they are pointing in the correct direction of the shortest path (or their path of choice based on noise, air quality, scenery, time taken, etc.) to their destination.

The *Haptic DestinationPointer* is a prototype designed to partially help the user explore (like Haptic WayPointer) the place while assisting them to navigate to the destination. This allows the user to "explore a place" and still not get completely lost or wander away too far from the destination.
At any location the user selects their destination and they are alerted when they are "pointing in the correct direction of the destination".

The user gets assistance through one or more pedestrian navigation systems discussed above to help them navigate to the destination. As they are nearing the destination of their choice, they need to be notified about distance to destination. In the following section we see how such a notification system using haptic feedback is useful to the user.

4.3 Haptic Alert

Location Based Notification Systems (LBNS) are those systems which convey information to the user related to their location using various visual, audio or haptic cues. The *Haptic Alert* is an LBNS that provides haptic feedback to the user using varied frequency/pattern of vibration to represent distance to a particular location. The users are provided with eyes-free and hands free feedback by alerting them even if the device is placed in a bag or pant pocket and the user not having to explicitly perform any scanning/searching. The benefit of such a system is highlighted by describing a *Haptic Transit* system that is useful for users of public transport to notify them about the arrival at a destination bus stop [24].

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5 CONCLUSION AND FINAL REMARKS

In this paper we describe our haptic interaction model which integrates three different types of mobile location based systems – knowledge discovery, pedestrian navigation and notification system.

There are some key outcomes from the integration of haptics as a modality into mobile location based services.
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 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.

The user trials carried out in order to test the usefulness of a Haptic Pedestrian showed that users were able to successfully navigate to the destination from a given origin purely based on haptic feedback. Tests also showed that users of haptic feedback based systems, based on their memory recall were able to prepare better maps of the area post the navigation tasks [12]. This shows that the cognitive burden on the user is reduced while using non-visual feedback techniques like haptics.

Enhancements to the current work could include integration of contextual information, detailed large-scale user trials and the exploration of using haptics within confined indoor spaces.

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REFERENCES

1. G. D., Abowd, C. G., Atkeson, J. Hong, S. Long, R., Kooper, and M. Pinkerton. (1997). "Cyberguide: a mobile context-aware tour guide". *Wireless Network*, Volume 3(5), pp 421–433.

2. A. K. Beeharee, and A. Steed, (2006). "A natural wayfinding exploiting photos in pedestrian navigation systems". *In Proceedings of the 8th conference on Human-computer interaction with mobile devices and services, MobileHCI '06,* pp 81–88, NY, USA, ACM.

3. J. M. Carroll, (2003). "1 Chapter - introduction: Toward a multidisciplinary science of human-computer interaction". *In Carroll, J. M., editor, HCI Models, Theories, and Framework*s, pp 1–9. Morgan Kaufmann, San Francisco.

4. Chittaro, L. (2004). "HCI aspects of mobile devices and services". *Personal Ubiquitous Computing*, Volume 8(2), pp 69–70.

5. R. Dale, and S. Geldof, (2005). "Using natural language generation in automatic route description". *In Journal of Research and Practice in Information Technology*, pp 89–105.

6. V. H. Ernst, and M. Ostrovskii, (2007). "Intelligent cartographic presentations for emergency situations". *In Proceedings of the 1st international conference on Mobile information technology for emergency response, MobileResponse'07,* pp 77–84, Berlin, Heidelberg. Springer-Verlag.

7. GoogleMaps (2013). Map based web-service: http://www.google.ie/mobile/maps/. Last accessed: July 2013.

8. S. Holland, D.R. Morse, and H. Gedenryd, (2002). "Audiogps: Spatial audio navigation with a minimal attention interface". *Personal Ubiquitous Computing*, Volume 6(4), pp 253–259.

9. H. Hile, R. Vedantham, G. Cuellar, A. Liu, N. Gelfand, R. Grzeszczuk, and G. Borriello, (2008). "Landmark-based pedestrian navigation from collections of geotagged photos". *In Proceedings of the 7th International Conference*

ISBN: 978-0-9891305-0-9 ©2013 SDIWC

*on Mobile and Ubiquitous Multimedi*a, MUM ’08, pp 145–152, New York, NY, ACM.

10. R. Jacob, P. Mooney, and A.C. Winstanley. (2011) “Guided by touch: Tactile pedestrian navigation”, *1st Mobile Location Based Services (MLBS) Workshop in conjunction with the 13th ACM International Conference on Ubiquitous Computing*, pp. 110-120.

11. R. Jacob, P. Mooney, and A.C. Winstanley. (2012). “What’s up that street? Exploring streets using a haptic geowand”. In Gartner, G. and Ortag, F., editors, *Advances in Location-Based Services, Lecture Notes in Geoinformation and Cartography*, pp 91–105. Springer Berlin Heidelberg.

12. R. Jacob, A.C. Winstanley, N. Togher, R. Roche, P. Mooney (2012). “Pedestrian navigation using the sense of touch”, *Computers, Environment and Urban Systems, Special Issue: Advances in Geocomputation*, Volume 36, Issue 6, November 2012, pp 513-525, Elsevier.

13. S. Kim, and A. K. Dey, (2010). “AR interfacing with prototype 3d applications based on user-centered interactivity. *Computer Aided Design*, Volume 42(5), pp 373–386.

14. J. M. Loomis, R. G. Golledge, and R. L. Klatzky, (1998). “Navigation system for the blind: Auditory display modes and guidance”. *Presence: Teleoper. Virtual Environment*, Volume 7(2), pp 193–203.

15. P. Nemirovsky, and G. Davenport, (1999). “Guideshoes: navigation based on musical pattern”s. *In CHI ’99 extended abstracts on Human factors in computing systems*, CHI EA ’99, pp 266–267, New York, NY, USA. ACM.

16. A. Nurminen, and A. Oulasvirta, (2008). “Designing interactions for navigation in 3D mobile maps”. *In Meng, L., Zipf, A., and Winter, S., editors, Map-based Mobile Services, Lecture Notes in Geoinformation and Cartography*, pp 198–227. Springer Berlin Heidelberg.

17. M. Pielot, B. Poppinga, and S. Boll, (2010). “Pocketnavigator: vibro-tactile waypoint navigation for everyday mobile devices”. *In Proceedings of the 12th international conference on Human computer interaction with mobile devices and services, MobileHCI ’10*, pp 423–426, New York, NY, USA. ACM.

18. A. Rahajaniaina, and J.P. Jessel, (2010). “Visualization of distributed parcel’s information on mobile device”. *In Proceedings of the 2010 Second International Conference on Advanced Geographic Information Systems, Applications, and Services, GEOPROCESSING ’10*, pp 27–32, Washington, DC, USA. IEEE Computer Society.

19. M. Raubal, and S. Winter, (2002). Enriching wayfinding instructions with local landmarks”. *In Proceedings of the Second International Conference on Geographic Information Science, GIScience ’02*, pp 243–259, London, UK. Springer-Verlag.

20. T. Reichenbacher, (2001). “The world in your pocket towards a mobile cartography. *In Proceedings. of the 20th International Cartographic Conference*, pp 2514–2521.

21. S. Robinson, P. Eslambolchilar, and M. Jones, (2008). “Point-to-GeoBlog: Gestures and sensors to support user generated content creation”. *In MobileHCI ’08: Proceedings of the 10th* New York *International Conference on Human-Computer Interaction with Mobile Devices and Services*, pp 197–206, , NY, USA. ACM.

22. S. Robinson, M. Jones, P. Eslambolchilar, R. Murray-Smith, and M. Lindborg, (2010). “I did it my way: moving away from the tyranny of turn-by-turn pedestrian navigation”. *In Proceedings of the 12th international conference on Human computer interaction with mobile devices and services, MobileHCI ’10*, pp 341–344, New York, NY, USA. ACM.

23. J. Schoning, A. Kruger, K. Cheverst, M. Rohs, M. Lochtefeld, and F. Taher, (2009). “Photomap: using spontaneously taken images of public maps for pedestrian navigation tasks on mobile devices”. *In Proceedings of the 11th International Conference on Human-Computer Interaction with Mobile Devices and Services, MobileHCI ’09*, pp 14:1–14:10, New York, NY, USA. ACM.

24. B. Shalaik, R. Jacob, P. Mooney, and A.C. Winstanley. (2012a). “Using haptics as an alternative to visual map interfaces for public transport information systems”, *UbiCC Journal, Special Issue: Visual Interfaces and User Experience: New Approaches*, Volume 7, pp 1280–1292. UBICC Publishing Services.

ISBN: 978-0-9891305-0-9 ©2013 SDIWC

25. R. Simon, H. Kunczier, and H. Anegg, (2007). “Towards orientation-aware location based mobile services”. *In Gartner, G., Cartwright, W. E., and Peterson, M. P., editors, Location Based Services and TeleCartography*, Lecture Notes in Geoinformation and Cartography, pp 279–290. Springer.

26. R. Simon, P. Frohlich, and T. Grechenig, (2008). “Geo-pointing: evaluating the performance of orientation-aware location-based interaction under real-world conditions”. *Journal of Location Based Services*, Volume 2(1), pp 24–40.

27. S. Strachan, and R. Murray-Smith, (2009). “Bearing-based selection in mobile spatial interaction”. *Personal Ubiquitous Computing*, Volume 13(4), pp 265–280.

28. B. Walther-Franks, D. Wenig, R. Malaka, and B. Gruter (2009). “An evaluation of authoring interfaces for image-based navigation”. *In Proceedings of the 11th International Conference on Human-Computer Interaction with Mobile Devices and Services, MobileHCI ’09*, pp 58:1–58:2, New York, NY, USA. ACM.

29. D. Wenig, and R. Malaka,(2010). “Interaction with combinations of maps and images for pedestrian navigation and virtual exploration”. *In Proceedings of the 12th international conference on Human computer interaction with mobile devices and services, MobileHCI ’10*, pp 377–378, New York, NY, USA. ACM.

30. Wikitude (2013). “Augmented reality browser: http://www.wikitude.com/en/”. Last accessed: July 2013

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