Tracking Indoor Location and Motion for Navigational Assistance

Nektarios Paisios, Alex Rubinsteyn,
Matt Tierney, Lakshmi Subramanian
{nektar,alexr,tierney,lakshmi}@cs.nyu.edu
New York University
251 Mercer St., New York, NY 10012

Vrutti Vyas
vruttivyas@gmail.com
Polytechnic Institute of NYU
Metrotech Center, Brooklyn, NY 11201

ABSTRACT
Visually impaired people have a harder time remembering their way around complex unfamiliar buildings, whilst obtaining the help of a sighted guide is not always possible or desirable. By sensing the users location and motion, however, mobile phone software can provide navigational assistance in such situations, obviating the need of human guides. We present a simple to operate and highly usable mobile navigational guide that uses Wi-Fi and accelerometer sensors to help the user repeat paths that were already walked once.

Author Keywords
Navigational System, Mobile Phone, Wi-Fi Localization, Bayesian Filter, Visually Impaired.

ACM Classification Keywords
H.5.2 User Interfaces: User Centered Design, Prototyping.; C.2 Computer Communication Networks: Miscellaneous; K.4.2 Computers and Society: Social Issues - Assistive Technologies for Persons with Disabilities

General Terms
Algorithms, Design, Measurement, Experimentation

INTRODUCTION
Visually impaired people might need many hours of professional mobility training in order to get familiarized with a new indoor environment, such as their new place of employment. We present mobile phone software which allows the user to record a route inside a building, including its turns and important places of interest, such as The Door to my Office. The system can then help guide the user on the same path. During the training phase, the system correlates the physical trajectory of the user with the Wi-Fi and accelerometer sensor readings from the mobile device to construct a topological map of each path. For navigation, the system uses the same sensors to navigate the user to any pre-recorded end-point. The large body of prior work on Wi-Fi localization [1], demonstrate localization accuracies of around 1 M. However, such accuracies were achieved after extensive training and data gathering. We argue that the accuracy of location estimation required for navigating a visually impaired user does not need to be so high and especially that it should not come with such a high training tax. Previous systems offering navigational assistance such as [6, 8] either require GPS coverage or necessitate the existence of detailed maps. Other solutions geared towards blind users were found burdensome to carry or require expensive ultrasonic / laser sensors, [7, 5]. Employing building structure models, [4], RFID tags, [9] or server farms, [3], involve a high installation burden. In our system, we only require the user to walk a particular route once, with perhaps the help of a sighted guide, before the system can provide navigational assistance. Visually impaired users have to make extensive use of their senses of hearing and touch in order to avoid obstacles. Contrary to previous work, our system uses vibratory feedback and swipe gestures for the majority of user interactions, whilst it makes only judicial use of speech recognition and a screen reader.

A MOBILE NAVIGATIONAL GUIDE
During training, the user walks a route and records turns using swipe gestures on the phones touch screen, a quick input method that offers minimal destructions to blind individuals. Meanwhile, the user records any landmarks via speech recognition so that touch-typing is avoided. After completing the route, a topological map is computed by combining Wi-Fi fingerprints with accelerometer data. For navigating on a previously traversed route, the user can start from any point on that route and choose, using the phones screen reader, a specific end-point or landmark on that route to be the destination. The system directs the user to walk straight for a number of steps or to turn accordingly. Turns are additionally pre-announced in advanced, whilst if the user has taken a completely wrong direction he can be guided to turn around. However, the system might not be able to take corrective action in all cases that the user has geared off the recorded path or if the Wi-Fi topology has changed drastically. For constructing the topological map, we group sequential sets of Wi-Fi probes which exhibit similar signal

UIST'11, October 16–19, 2011, Santa Barbara, California, USA.
ACM 978-1-4503-1014-7/11/10.

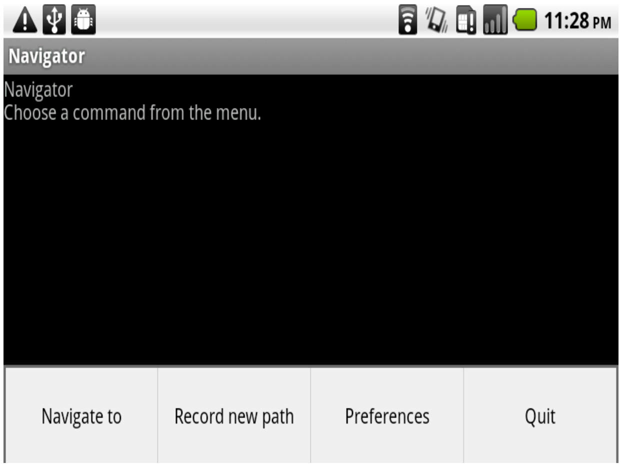

Figure 1. Application Menu

characteristics into nodes. To determine the similarity of pairs of Wi-Fi signal vectors (x, y) to one another, the Radial Basis Similarity Function (RBF) is used: For providing navigation, we utilize the Bayesian filtering framework, [2], in order to integrate our estimate of the Wi-Fi signal distribution at each location with a model of how much this distribution changes as a person walks. We calculate the number of steps walked by analyzing the periodicity peaks in the phone's accelerometer signal. The perceptual model of the Bayesian filter is simply the distribution of RBF similarities between all nodes in our map and the current Wi-Fi scan. The transition probabilities of our Bayesian filter capture the spatial connectivity of map nodes and how the systems state changes as the user walks. They are calibrated in an on-line manner as the user is navigating, based on the users walking speed, which effectively increases or decreases their magnitude depending on the users previous and current estimated locations.

EVALUATING NAVIGATIONAL QUALITY

A totally blind user has used our system across 2 separate buildings and on 4 different floors, across 23 paths which ranged in complexity. The user was able to successfully navigate all the paths in the system and only in one path, did the user take a delayed turn. Around 56% of the turn instructions were issued upon arriving at the exact physical location of the turn or after waiting for some seconds, whilst around 28% were issued a little bit early, (2-5 feet in advanced), and around 13% were given at 6-8 feet in advance. Concerning announcing the arrival to the destination, only around 2 announcements took place 2-4 feet before the actual destination, whilst 2 announcements were given 8-10 feet in advance. Overall, no instructions, safe one turn and one destination announcement, were issued either late or missed completely by the system, indicating the practical usefulness of our navigational algorithm.

CONCLUSION

We have presented a practical and useful navigational aid, which can remind visually impaired users how to independently find their way on any route they had previously traversed once. Its minimalistic gesture-base interface has made it simple to operate even while holding a cane or trying to listen to environmental sounds. Despite the high amount of training or the expensive sensors required in previous work, our system seems to be very accurate for navigational purposes as only on one out of the 23 tested paths, our user was given a belated turn instruction only by a few seconds.

REFERENCES

1. K. Chintalapudi, A. Padmanabha Iyer, and V. Padmanabhan. Indoor localization without the pain. In *Proceedings of the sixteenth annual international conference on Mobile computing and networking*, pages 173–184. ACM, 2010.
2. D. Fox, J. Hightower, L. Liao, D. Schulz, and G. Borriello. Bayesian filtering for location estimation. *IEEE Pervasive Computing*, pages 24–33, 2003.
3. A. Hub, J. Diepstraten, and T. Ertl. Design and development of an indoor navigation and object identification system for the blind. *ACM SIGACCESS Accessibility and Computing*, (77-78):147–152, 2003.
4. C. Jacquet, Y. Bourda, and Y. Bellik. A context-aware locomotion assistance device for the blind. *People and Computers XVIIIDesign for Life*, pages 315–328, 2005.
5. V. Kulyukin, C. Gharpure, P. Sute, N. De Graw, J. Nicholson, and S. Pavithran. A robotic wayfinding system for the visually impaired. In *PROCEEDINGS OF THE NATIONAL CONFERENCE ON ARTIFICIAL INTELLIGENCE*, pages 864–869. Menlo Park, CA; Cambridge, MA; London; AAAI Press; MIT Press; 1999, 2004.
6. A. Liu, H. Hile, G. Borriello, P. Brown, M. Harniss, H. Kautz, and K. Johnson. Customizing directions in an automated wayfinding system for individuals with cognitive impairment. In *Proceedings of the 11th international ACM SIGACCESS conference on Computers and accessibility*, pages 27–34. ACM, 2009.
7. L. Ran, S. Helal, and S. Moore. Drishti: an integrated indoor/outdoor blind navigation system and service. 2004.
8. Z. Wang, B. Li, T. Hedgpeth, and T. Haven. Instant tactile-audio map: Enabling access to digital maps for people with visual impairment. In *Proceedings of the 11th international ACM SIGACCESS conference on Computers and accessibility*, pages 43–50. ACM, 2009.
9. S. Willis and S. Helal. RFID information grid for blind navigation and wayfinding. In *Wearable Computers, 2005. Proceedings. Ninth IEEE International Symposium on*, pages 34–37. IEEE, 2005.