GETA Sandals: Walk Away with Localization

Shun-yuan Yeh, Keng-hao Chang, Chon-in Wu, Okuda Kenji, Hao-hua Chu
National Taiwan University
#1 Roosevelt Road, Section 4, Taipei, Taiwan 106
Tel: 8862-2362-5336
{r93124, r93018, r92079, r90092, hchu}@csie.ntu.edu.tw

ABSTRACT

The GETA sandals are Japanese wooden sandals embedded with location tracking devices. By wearing them, the GETA sandals can track anywhere a user walks to. The GETA sandals work both in the indoor and outdoor environments. The motivation for the GETA sandals is to create a location system that needs minimum infrastructural setup and support in the environment, making it easy for deployment in everyday environments. This is in contrast to most of the current indoor location systems based on WiFi or ultrasound, which need to setup access points, fixed transmitters and receivers in the environment. The GETA sandals track a user's location using a footprint-based method. The footprint-based method uses location sensors installed underneath the GETA sandals to continuously measure the displacement vectors formed between the left and right sandals along a trail of advancing footprints. By progressively adding up these displacement vectors, the GETA sandals can calculate the user's current location anytime anywhere.

INTRODUCTION

Physical locations of people and objects have been one of the most widely used context information in context-aware applications. To enable such location-aware applications in the indoor environment, many indoor location systems have been proposed in the past decade, such as Active Badge [1], Active Bat [2], Cricket [3], RADAR [4], and Ekahau [6]. However, we have seen very limited market success of these indoor location systems outside of academic and industrial research labs. The main obstacle that prevents their widespread adoption is that they require certain level of system infrastructural support (including hardware, installation, calibration, maintenance, etc.) inside the deployed environments. For examples, Active Badge [1], Active Bat [2], and Cricket location systems [3] require the installation of infrared/ultrasonic transmitters (or receivers) at fixed locations (e.g., ceilings or high walls) in the environments. In order to attain high location accuracy and good coverage, the system infrastructure requires large number of transmitters (or receivers) installed in the deployed environments. This is beyond the reach of ordinary people to afford, operate, and maintain the infrastructure. WiFi based location systems such as RADAR [4] and Ekahau [6] require an existing WiFi network in the deployed environment. For example, the Ekahau location system recommends a WiFi client to be able to receive signals from 3~4 WiFi access points in order to attain the specified location accuracy of 3 meters. This high density of access points is unlikely in our everyday home and small office environments. In addition, most WiFi based location systems require users' calibration efforts to construct a radio map by taking measurements of WiFi signal strength at various points in the environment. This forms another barrier for users.

Significantly reducing the needed system infrastructure serves as our main motivation to design and prototype a new footprint location system on traditional Japanese GETA (pronounced "gue-ta") sandals.

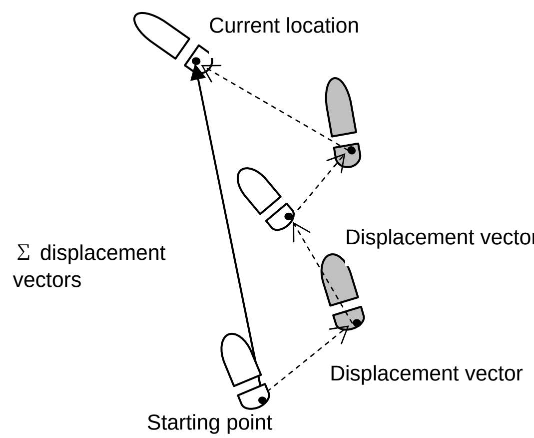

Figure 1. Add up displacement vector to compute current location in the footprint method.

FOOTPRINT LOCATION SYSTEM

This footprint location system computes a user's physical location solely by using sensors installed on the GETA sandals. To enable location tracking, a user simply has to wear the GETA sandals with no extra user setup & calibration effort. The basic idea of the footprint location system can be described by looking at a person walking from location A to location B on a beach shown in Figure 1. He/she will leave a trial of footprints. To track a person's physical location, the system continuously measures a displacement vector formed between two advancing footprints (advancing in the temporal sense). To track a user's current location relative to a starting point, the system simply sums up all previous footprint displacement vectors leading to his/her current footprint location.

The footprint location system has been prototyped using the following four sensor components shown in Figure 2: (1) pressure sensors, (2) ultrasonic transmitter/receivers, (3) orientation sensor, and (4) RFID tags and readers. Two pressure sensors, installed at the bottom of both sandals, are used to detect when both feet are on the ground, forming a full step. At that time, the ultrasonic transmitter at the right sandal transmits a beacon toward the two ultrasonic receivers at the left sandal. Using time-of-flight information and triangulation method, the footprint location system can compute the displacement vector between left and right sandals. The reading from the orientation sensor is used to re-orient the displacement vector measured by a local coordinate system to a global coordinate system.

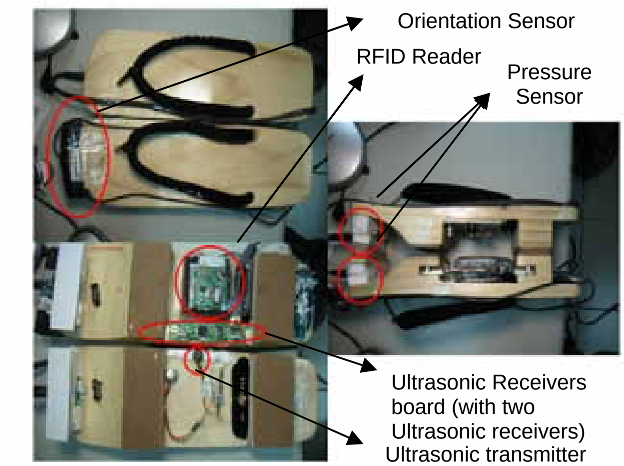

Figure 2. Sensor components used in footprint location system.

Figure 3. Location tracking of GETA sandals.

The footprint location system has a drawback that positioning error accumulates as the number of footsteps increases. It is inevitable that a small amount of error is introduced each time we take measurements to calculate a displacement vector. Consider a user has walked *n* steps away from a starting point: his/her current location is calculated as a sum of these *n* displacement vectors, the current location error is also the sum of all errors from these previous displacement vectors. In other words, the error in the current footprint measurement will be a percentage of the total distance traveled. To bound this error accumulation, we utilize a RFID reader at bottom of left sandal, and place a small number of RFID tags with known location coordinates in the environment. When a user steps on a location-aware RFID tag, the RFID reader reads off the correct coordinate from the tag; therefore, bounding the error in the footprint location system. Although these location-aware RFID tags are infrastructural components, they constitute only *light* infrastructure, given that RFID tags are relatively inexpensive in cost (< $1 each), and they are relatively easy to install by most people. Based on our current measurements, the error without RFID tags is approximately 1% ~ 5% of the distance traveled, mostly depending on the type and precision of the orientation sensors used. To limit the error to 1 meter, we only need to place approximately one tag every 100 or 20 meters.

The actual working of the GETA sandals is shown in Figure 3. The dot on the map shows the current location of the user.

FUTURE WORK

We have found several limitations in the GETA sandals [5] to overcome in our future work. Stair climbing is one such limitation because the stair becomes the obstacle blocking the ultrasonic sensors between two sandals. To address this limitation, we would like to try accelerometers and acceleration readings to estimate the displacement vector. We would also like to improve the wear-ability of the system. The current wear-ability is unsatisfactory due to interconnecting all sensor components to a Notebook PC through hardwiring. In our next prototype, we would like to replace all hardwiring with wireless networking (e.g., Bluetooth), and replace processing on the Notebook with a small embedded processor.

ACKNOWLEDGMENTS

We would like to thank Taiwan NSC and Quanta Computer for their general supports under NSC grants #93-2213-E-002-088, #93-2218-E-002-146, and #93-2622-E-002-033.

REFERENCES

[1] R. Want, A. Hopper, V. Falcao, J. Gibbons. The Active Badge Location System. ACM Transaction on Information Systems, 10:1, pp. 91-102, 1992.

[2] A. Harter, A. Hopper, P. Steggles, A. Ward, P. Webster. The anatomy of a context-aware application. In Proc. of 5th MOBICOM, pages 59–68, 1999.

[3] N. B. Priyantha, A. Chakraborty, H. Balakrishnan. The Cricket Location-Support System. In Proc. of the 6th MOBICOM, Boston, MA, USA, August 2000.

[4] P. Bahl, V. Padmanabhan. RADAR: An In-Building RF-based User Location and Tracking System. In Proc. of the IEEE INFOCOM 2000, pages 775-784, March, 2000.

[5] Okuda Kenji, Shun-yuan Yeh, Chon-in Wu, Keng-hao Chang, Hao-hua Chu. The Geta Sandals: A Footprint Location Tracking System, Workshop on Location- and Context-Awareness (LoCa 2005, in Cooperation with Pervasive 2005), Munich, Germany, May 2005. (also published as Lecture Notes in Computer Science by Springer).

[6] Ekahau, http://www.ekahau.com