Indoor-Outdoor Navigation System for Visually-Impaired Pedestrians: Preliminary Evaluation of Position Measurement and Obstacle Display

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Abstract

This paper reports on a preliminary evaluation of position measurement and obstacle display in a navigation system for visually-impaired pedestrians on a real-city course including indoor and outdoor areas.

1. Introduction

Navigation systems have a critically important role to play in opening up the more activities to people with visual impairments. However, previous approaches have serious deficiencies in positioning measurement. For instance, GPS is not available indoors and often suffers from serious errors caused by multipath propagation [1]. Unuma [2] proposed a scheme that combines RFID tags embedded in Braille blocks with pedestrian dead reckoning (PDR), but it inevitably involves the deployment of a large-scale dedicated infrastructure.

We have developed a system that provides extensive support of visually-impaired-pedestrians over a wide area both indoors and outdoors. Our system (Figure 1) obtains positioning data from several sensing sources such as GPS, Wi-Fi (PlaceEngine), PDR [3][4], image-based registration [5], and active RFID (if the infrastructure is in place), and integrates them based on each uncertainty. We also employ road-network data for map matching. To ensure visually-impaired pedestrians can move about in relative safety, the system is equipped with a laser range finder (LRF) to detect obstacles in the path ahead of the user. A tactile display (Braille Sense Plus by GW Micro) is applied for not only Braille but obstacle-map display.

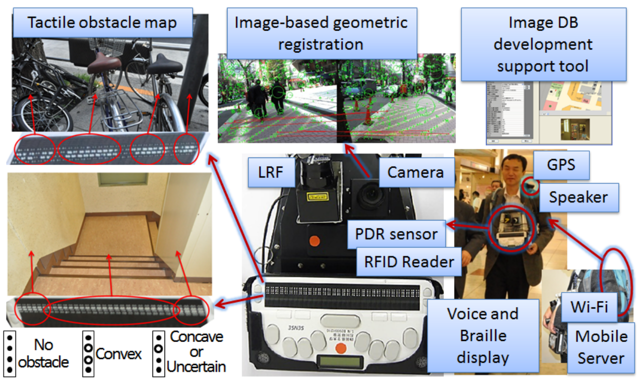

Figure 1. Overview of indoor-outdoor navigation system for visually-impaired pedestrians.

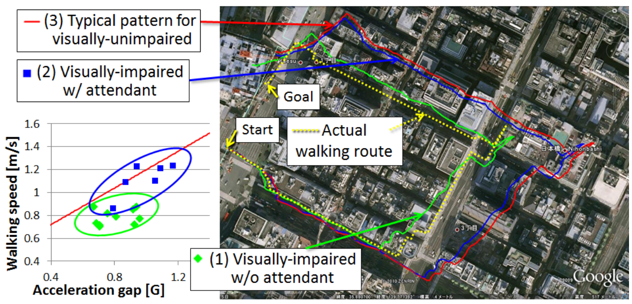

Figure 2. Walking speed parameters for visually-impaired and unimpaired subjects.

2. DR for Visually-Impaired Pedestrians

Before actual trials, we investigated the difference of walking patterns between normal-sighted people and visually-impaired people to comprehend the effects on the performance of PDR. In this investigation, first, a visually-impaired (totally blind) subject walked by himself with a cane, and then walked with an attendant to record self-contained sensor data (accelerometers, gyroscopes, and magnetometers). The results showed that the acceleration amplitude and speed distribution of the subject walking without attendance substantially deviated on the low side compared to the regression line that corresponds to the typical pattern for the unimpaired subjects. When walking with attendance, on the other hand, we observed slight deviation from the regression line, but the results were close on the whole (Figure 2-left). It indicates that PDR can work appropriately by just changing the walking speed parameters according to whether the user walks with attendance or not.

In order to verify this finding, we collected sensor data for the same subject without attendance on a trial course that is the same as in Figure 3, and calculated the trajectories offline by using the parameters for the cases of (1)~(3) in Figure 2-right. As a result of the comparison, the trajectory calculated with the parameters for (1) was much closer to the actual walking route than the ones with the parameters for (2) and (3).

3. Evaluation at a Real-City Course

We conducted a comparative evaluation of the position measuring technologies implemented in our system on a real-city course. Table 1 summarizes each positioning error and coverage. In Figure 3, we superimposed each trajectory onto the site maps. GPS only covers the outdoor portions of the route, and the results are quite blurred even in some exposed areas due to multipath errors and other disturbances. Wi-Fi positioning provides positioning both indoors and outdoors. Our project staffs gathered access point data from scratch for the underground mall, so the Wi-Fi yielded fairly accurate indoor positioning compared to outdoors where we used an existing open database (DB).

PDR estimated the trajectory with practical accuracy throughout the course. However, this good performance can be attributed to the fact that there were few points of geomagnetic disturbance, so there was no gyro drift problem. Our overall evaluation of PDR [3][4] is that it generates errors on 2-5% to the total distance walked. Image-based registration employed a DB that only contained scenes along the course, so naturally it yielded accurate positioning. Accuracy when navigating routes that are not predetermined calls for further study, but one can easily envision scenarios where the DB is confined based on other sensors. RFID tags were planted about every 20 meters throughout indoors for the trial, and this yielded fairly stable positioning within the coverage area. Needless to say, it would require an immense infrastructure to implement this kind of environment. Sensor fusion provided better accuracy than the disparate sensor sources. In map matching, the route data represent each sidewalk as a line, so corrections force positions to adhere to the lines even when the sensor data is correct. This tends to generate more errors than the sensor fusion results. But considering the various circumstances, this is probably necessary to obtain stable results.

4. Obstacle Detection and Tactile Display

The LRF performs a 1-D laser scan ahead and detects irregularities up to two meters out and ± 60 degrees to the left and the right of the pedestrian's path. The Braille display consists of 64-by-4 pins. The pins in the horizontal direction correspond to the left and right of the user, while pins in the vertical direction correspond to three conditions (Figure 1). We conducted a series of detection experiments both indoors and outdoors at the Yaesu site using a variety of obstacles. Obstacles were detected at 24 out of 29 places (83% accuracy), and the information was conveyed tactually enabling the visually-impaired users to intuitively and comprehensively monitor which direction convex and concave obstacles are located in with their palm.

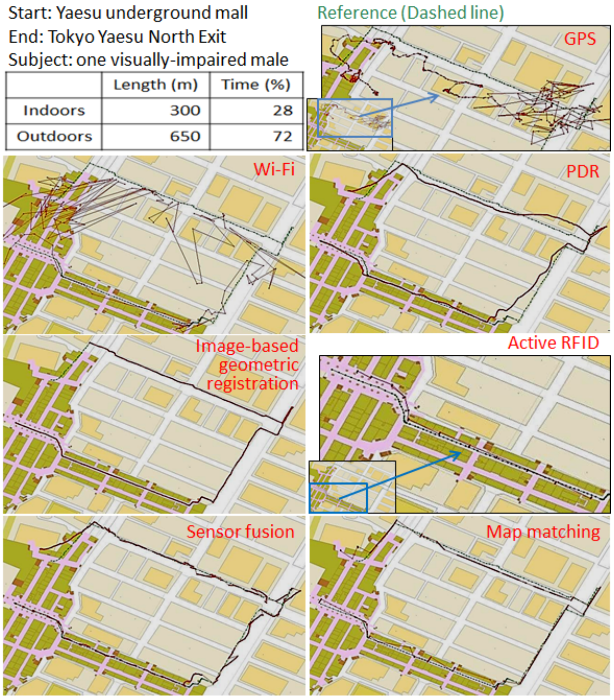

Figure 3. Overview of trajectories obtained with each sensor and method.

Table 1. Positioning error and coverage on the trial course of each sensor and method.

Method / Err. (m)	GPS	Wi-Fi	PDR	Image-based registration	Active RFID	Sensor fusion	Map matching
RMSE	31.6	44.1	10.8	3.3	6.9	6.7	9.3
Max	148.8	139.1	24.7	77.5	18.8	27.7	45.5
Min	1.6	2.8	1.4	0.0	0.3	0.0	0.3
SD	18.6	33.7	4.5	12.9	4.3	5.5	7.5
Coverage(%)	56.0	98.9	99.5	99.5	22.3	99.4	99.4

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