Pedestrian Dead Reckoning and its applications

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ABSTRACT

First, we briefly introduce the technologies of PDR (Pedestrian Dead Reckoning) that can be used to track the location and orientation of a pedestrian. Secondly, we show some enhancement of the PDR to improve its performance on accuracy. Finally, we describe the applications of the PDR.

KEYWORDS: Pedestrian Dead Reckoning, Pedestrian navigation system

INDEX TERMS: K.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems□Artificial, augmented, and virtual realities; I.4.8 [Image Processing and Computer Vision]: Scene Analysis□Sensor fusion.

1 INTRODUCTION

Recently, the PDR technologies draw strong attention from many fields of industries since by using the self-contained sensors (ex. accelerometers, gyrosensors, magnetometers and barometers) the PDR can be utilized to track location and orientation of pedestrians indoors where the GPS signal is blocked and becomes unavailable. Compared to the INS (inertial navigation system), the PDR has several advantages on cost, weight and energy consumption of the system thanks to the recent rapid advancement of the MEMS (microelectromechanical system) sensing components. The PDR is classified into two categories by the equipped position of the self-contained sensors on the pedestrian: (a) waist-mounted and (b) shoe-mounted [3]. We took the former approach on PDR since the equipped position allows the system to gather information about the user's action such as walking, going-up/down stairs, standing-up and sitting-down on a chair.

2 BASICS OF PEDESTRIAN DEAD RECKONING

The PDR is composed of the three key technologies: (a) tracking of the sensor's attitude, (b) detection of walking locomotion and (c) estimation of the walking velocity. In this section, we briefly describe the key technologies.

2.1 Tracking of the sensor's attitude

The attitude consists of the gravitational and the horizontal reference (north) components. They are estimated and updated by the Kalman filtering framework [1][2]. The gravitation can be directly observed by accelerometers and the north direction can be observed by the magnetometers. As the magnetic field measured by the sensors is often distorted by local structures of the environment, we use a selective mechanism to filter out the disturbance for the observation on the north direction [1]. The state vector of the Kalman filter is predicted by the angular velocity vector from the gyrosensors.

2.2 Detection of walking locomotion

Since human walking locomotion is highly coordinated, the pattern of motion repeatedly appears in acceleration and angular velocity. If the sensors are placed on the waist which is near the center of gravity of human body, the pattern can be easily recognized by detecting the pair of down-peak and up-peak of the components.

2.3 Estimation of the walking velocity

The walking velocity of pedestrians is empirically known to have strong linear correlation with the acceleration amplitude in the vertical direction within a walking cycle. By using linear regression, the equation to estimate the velocity from the accelerometers can be obtained. However, the linear regression parameters differ in person and thus a calibration procedure is required beforehand for more precise estimation of walking velocity.

3 ENHANCEMENT OF THE PDR

We introduce two enhancements of the PDR to improve its performance, by map matching and dynamic estimation of walking parameters from surveillance cameras.

Since the PDR is an incremental method of estimating location, its error is accumulated to significant amount over time. Therefore the accumulated error needs to be somehow reduced and corrected. We introduce the constraints of the environment (namely 2.5D map) to the PDR and mechanism to fuse the PDR results and the constraints by using particle filter.

As described in Section 2.3, the walking parameters are slightly different from person to person. Then, we use surveillance cameras to measure walking velocity in order to recalibrate the parameters. The camera can also be used to correct the estimated position by the PDR.

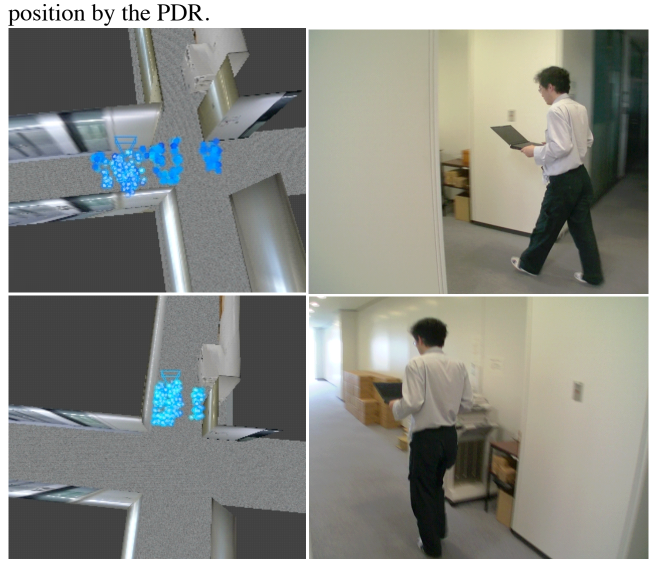

Figure 1. Map matching using a map converted from 3D environment model (Left-column presents probability distributions of locations of the user shown in right-column. Bottom-row presents the state one second before top-row).

3.1 Map matching and particle filter

The user's location and orientation are updated by fusing the measurements from the PDR estimation and 2.5D maps [4] generated from 3D environment models [6] and we use the particle filter framework for probabilistically fusing the data [5]. The particle filter which is kind of Bayesian filter efficiently estimates state of a system under the Markov assumption and Monte-Carlo approximation of probability distribution.

The state space of the particle filter is represented by the 4D vector whose components are 2D position, a polygon identification number of the 2.5D map, and an absolute orientation. In this state space, the probability distribution of the user's location is predicted from the estimated position, orientation, and its uncertainties. Note that, in the prediction process of the current probability distribution based on measurement from the PDR, a sample in those representing the probability distribution is eliminated when the displacement vector of the sample intersects with lines of walls or outgoes to outside of floors in the 2.5D map. This map matching improves the performance by utilizing knowledge of the environments. And the implementation of the map matching on a typical PC runs in real-time. The error of the PDR with map-matching is less than 5 percent of walking distance.

3.2 Dynamic estimation of walking parameters from surveillance video camera

We aim at improving localization performance by utilizing surveillance cameras used for surveillance service as existing infrastructure. The surveillance camera must be clearly placed in important areas of human traffic, so the feature is absolutely suitable for localization. The surveillance cameras are used for realizing the following two functions.

- Correction of localization error of the PDR
- Dynamic estimation of walking parameter

Camera has high-spatial resolution, and so its measurements are effective for estimating precise location of the pedestrian. In addition, the cameras can also be used to estimate the walking velocity of the pedestrian from the time-series measurements.

In order to realize above functions, our system needs to recognize the user wearing the self-contained sensor module from persons on the surveillance videos. Our system recognizes the user by matching and identifying two kinds of 2.5 D trajectories that are fusion-based trajectory and video-based trajectory. Here, the camera parameters to be used for converting 2D video-based trajectories into 2.5D video-based trajectories can be estimated by 3D environment models as contents and the 3D modeler described above from a photo without any special devices.

When the system successfully matches and identifies trajectories, the identified video-based trajectory is sent to the fusion unit for correction of localization errors. Moreover, the system estimates the walking velocity from the video-based trajectory and sends it to the part of walking parameter estimation in PDR. From the velocity and the acceleration amplitude, the system can estimate waking parameters by the method in [1][2].

4 APPLICATIONS OF THE PDR

We have developed two types of applications of the PDR technologies mentioned above. These applications are described in this section.

4.1 The PDR Evaluation Kit

We have commercialized the PDR technologies into an evaluation kit, which allows developers to test the accuracy and availability of localization. The kit includes the PDR software and a self-contained sensor module. It can be used to develop indoor and outdoor localization system such as a pedestrian navigation system and locating (and tracking) system of factory personnel. The evaluation kit can be purchased from SHIBUYA KOGYO at around 5,000 USD.

4.2 Application toward visually impaired people navigation

We are currently working on a national project that aims to develop an advanced mobile device which supports visually impaired people to work out streets safely and comfortably. Figure 2 shows a schematic outlook of the device.

One of the problems of visually impaired people navigation is the inaccuracy and unavailability of the positioning of the GPS-based navigation system. Our new device will navigate the visually impaired people more accurately by the help of new sensors including the PDR system described in this paper. The device exploits the GPS for rough position estimation and its bootstrapping, and then the PDR system estimates the position in a map. Additional vision system also gives position correction information by checking landmarks and pre-recorded images in a scene. It also has a voice navigation interface and a refreshable braille display so that we can inform navigation instruction flexibly. The device is planned to be released next spring.

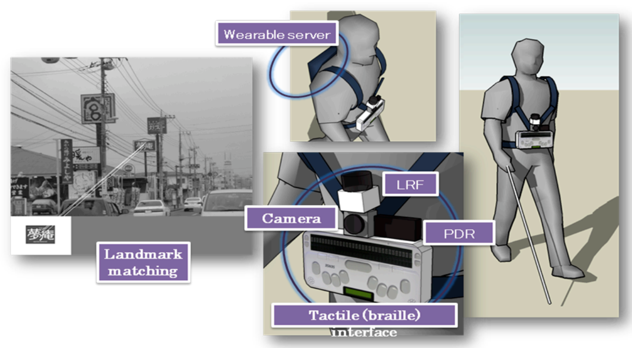

Figure 2. The navigation system for visually impaired people.

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