FootStep-Tracker: An Anchor-Free Indoor Localization System via Sensing Foot Steps

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Abstract

Recently, indoor localization has been a key supporting technology for most ubiquitous applications. However, most localization schemes require the deployment of the anchor nodes in advance to assist indoor localization. In this demo, we develop FootStep-Tracker, an indoor localization system via sensing the user's footsteps, without any support infrastructures. By embedding tiny Sensor-Tag into the user's shoes, FootStep-Tracker is able to accurately perceive the user's moving trace, including the moving direction and distance. Moreover, by detecting the user's activities such as going upstairs/downstairs and taking an elevator, FootStep-Tracker can correlate with the specified positions such as stairs and elevators, and determine the exacted moving traces in the indoor map.

Author Keywords

Indoor Localization; User Activity Sensing; Sensing Foot Steps.

ACM Classification Keywords

H.5.m [Information interfaces and presentation (e.g., HCI)]: Miscellaneous; See [http://acm.org/about/class/1998/]: for full list of ACM classifiers. This section is required.

Introduction

Nowadays, indoor localization schemes have been widely used to support various applications. The state art indoor localization schemes mainly leverage WiFi[1][3] or Bluetooth to locate the users in the indoor environment. In most cases, the deployment of anchor nodes such as WiFi APs and Bluetooth beacons is required in these schemes. However, for a number of indoor environments, deploying the localization anchor nodes is either impossible or rather expensive. Therefore, an anchor-free system for indoor localization is essential. In this demo, we develop FootStep-Tracker, an anchor-free indoor localization system purely based on sensing the user's footsteps.

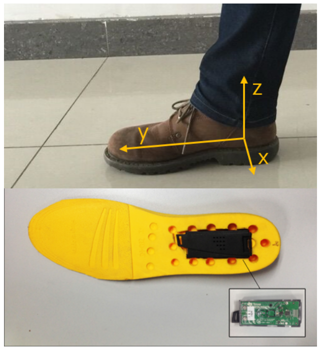

Figure 1: The SensorTag we used for FootStep-Tracker. We embed SensorTag into the insole in the shoes and send data to an Android smart phone via bluetooth.

System Design

As is shown in Figure 1, we embed the tiny sensor like the SensorTag [2] into the user's shoes. SensorTag collects and sends the sensors' data to an Android smart phone via bluetooth. The smart phone analyzes the data and illustrates the user's exact location in the indoor map. Figure 2 shows the framework of our system. FootStep-Tracker

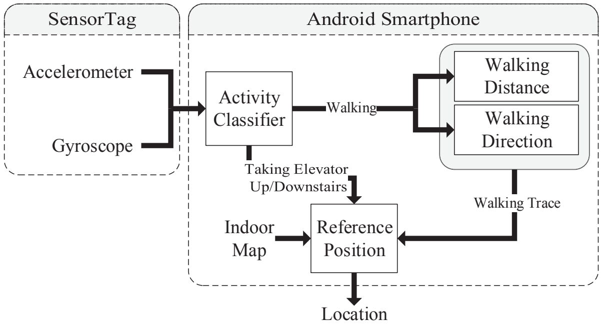

Figure 2: Framework of FootStep-Tracker.

depicts the user's moving trace by estimating the walking distance and walking direction. Besides, FootStep-Tracker references the position of stairs and elevators by detecting the user's activities such as going upstairs/downstairs and taking an elevator. By combining the moving trace and reference position, FootStep-Tracker can locate the user accurately on the given indoor map.

Activity Classifier. It extracts features from stream raw sensors' data. According to the extracted features, Activity Classifier classifies the user's current activities into different classes, by leveraging several classify techniques, such as Decision Tree and Support Vector Machine. Table 1 showes the label and description of eight classes.

Step Counter. It segments the walking data stream step by step according to the pattern of the accelerometer in walking activities. The segment data here is not only used for step counting, but also used for step length estimation.

Step Length Estimator. It measures the step length of each step. By intensively analyzing the foot movement dur-

Table 1: Label Description

UST	going upstairs
DST	going downstairs
WALK	walking
EHG	hypergravity in elevator.
EWL	weightlessness in elevator.
EUP	elevator going up
EDOWN	elevator going down
SS	stand still

ing walking, we build a geometric model to depict the movement and rotation of the insteps along one step. Based on the proposed model, we calibrate the step length estimation by efficiently employing the accelerometer combined with gyroscopes.

Step Direction Estimator. It measures the moving direction once we detect the turning steps from the heading forward steps. By merging consecutive turning steps in a whole turning process, and extracting the integral, max and variance as features, we classify the current turning directions into three classes: left turn, right turn and turn around.

Reference Position Estimator. It estimates the reference positions of the moving trace based on the current activity and an indoor map. As the location of elevators and stairs are fixed in the indoor environment, Reference Position Estimator treats the position of elevators or stairs as the reference position of the moving trace.

Evaluation

Classification accuracy of Activity Classifier. To evaluate the accuracy of the Activity Classifier, we embed the FootStep-Tracker into user's shoes and collect sensors' data. The Sensor-Tag's sample frequency is set as 10 Hz, and it is embedded in the insole as depicted in Figure 1. For each activity, we collect about 500 windows of accelerometer and gyroscope data among 5 different users. Then we use them to train the classify model. We perform the classifier on the previous 5 users and 3 new users. They go up/downstairs, walk or take elevator. Figure 3 (a) shows the accuracy of Activity Classifier on the collected data. Particularly, we don't evaluate the EUP/EDOWN because that EUP is the combination of EHG and EWL, and EDOWN is the combination of EWL and EHG. On average, we achieve a classification accuracy of 96.2%.

Location Accuracy. To evaluate the location performance of FootStep-Tracker, we tested it among 5 users. They wear FootStep-Tracker, walking along an approximately 100m-long path which is the full red line in Figure 3 (b) in our department building. Users taked the elevator (the left bottom one) down to this floor, and moved along the path. After he/she turned six times, he/she stopped at another elevator in the map, and we stopped the tracking. Figure 3 (c) shows the average location accuracy for each user. On average, the location accuracy is within 1m.

Demo Application

FootStep-Tracker interacts with user via an Android application. Figure 4 shows the snapshot of the application. When user connecting the SensorTag and moving in the indoor environment, the application timely reports the users' step number, moving trace, current activity, sensors' data and the user's location in the indoor map.

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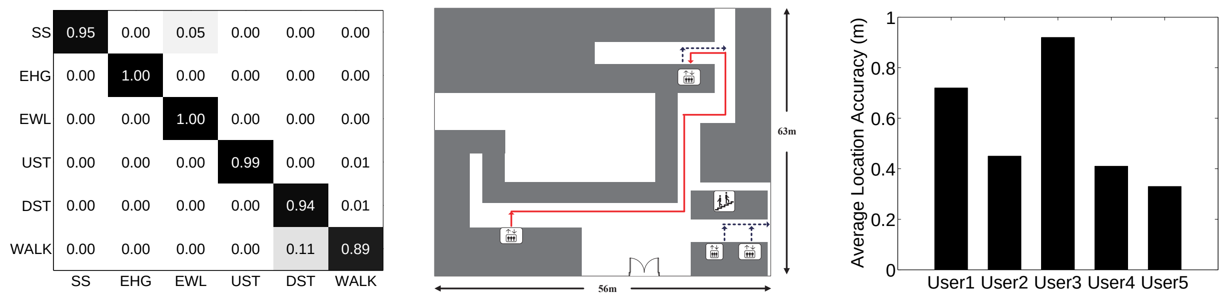

(a) Activity Classifier performance.

(a) Walking path.

(b) Location accuracy for each user.

Figure 3: System Evaluation.

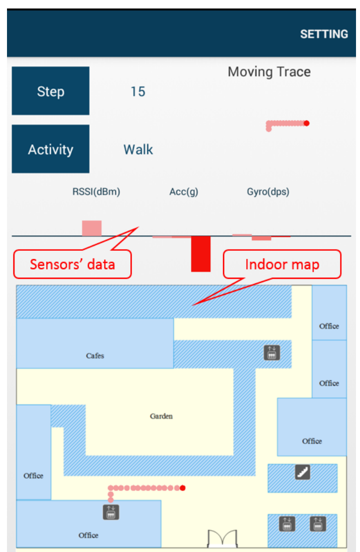

Figure 4: FootStep-Tracker App.

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