An Integrated Indoor BLE-SLAM System

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Content

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PART ONE

Background and Motivation

Background on BLE

◆ Bluetooth Low Energy is a wireless personal area network technology aimed at novel applications in the health care, fitness, beacons, security and localization.

◆ Compared to Classic Bluetooth, BLE is intended to provide considerably reduced power consumption and cost while maintaining a similar communication range.

Motivation

Recent years, We have seen a lot of SLAM algorithms being used in indoor positioning system as Wi-Fi SLAM. However, there is seldom no SLAM algorithm based on Bluetooth Low Energy.

We propose a received signal strength indication (RSSI) and Dead Reckoning (DR) based Bluetooth positioning method and design a fancy SLAM algorithm integrating the training and locating procedures into a non-divided system. In order to reduce the influence of positioning accuracy due to the abnormal RSSI, we implement a particle filter to help pre-process the signals. Besides, K-NN algorithm is utilized to construct maps of indoor environments.

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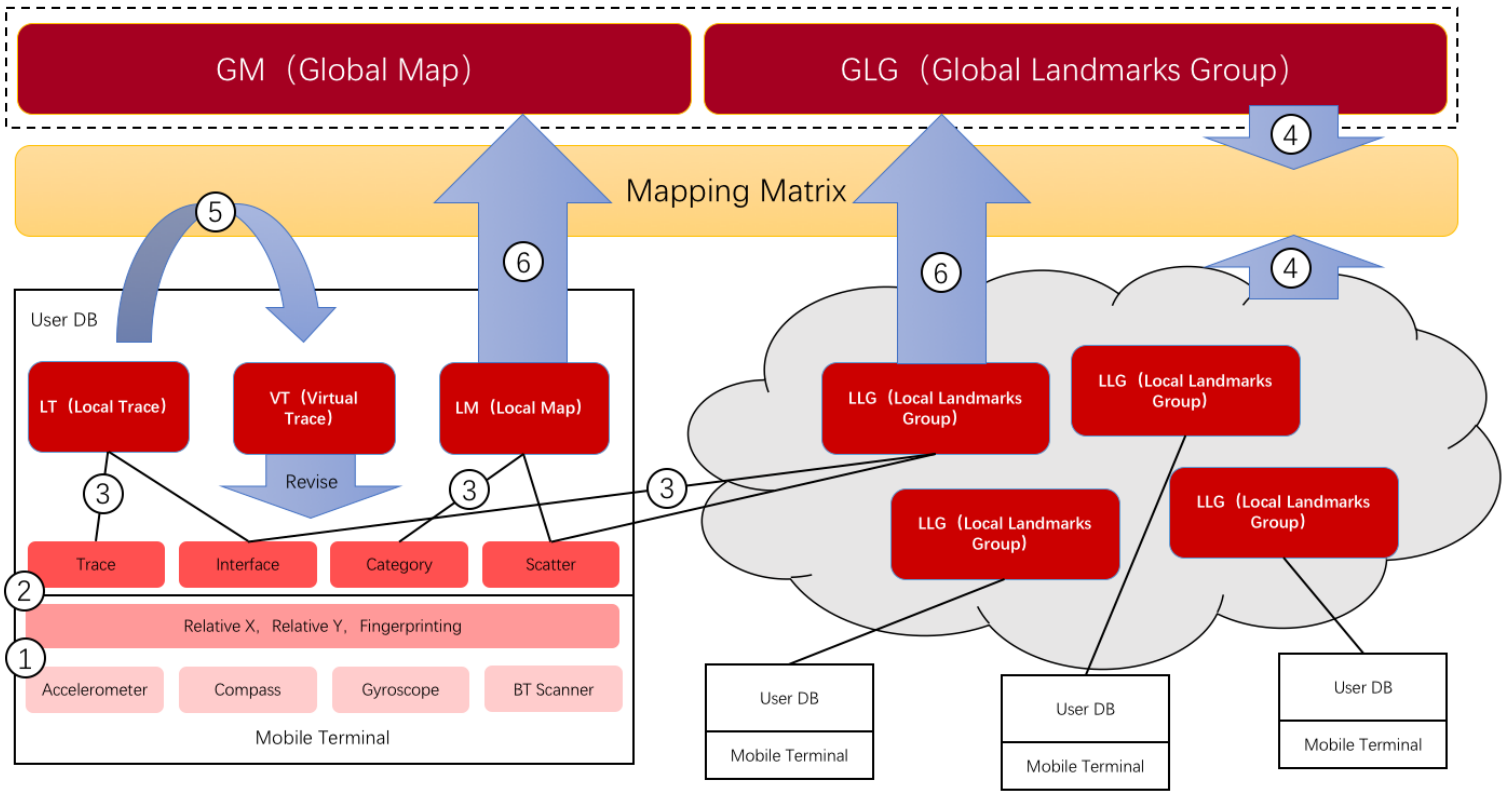
PART TWO

Integrated System



Our system consists of a trace-collection module and a positioning module, both of which exploit multiple sensors in a smartphone, such as accelerometer, gyroscope, magnetometer, etc.

Main Contribution

- Identify the last-mile navigation problem and propose a fancy algorithm which fuses training and positioning phase into a whole part.

- Propose an algorithm to increase the accuracy of users' traces detection. Exploit and integrate presented algorithm like Most-likelihood, K-NN and particle filtering algorithms in our system.

- Can construct the map of indoor environment passively which means with little pain.

Main Modules

The overall FOLLOWME system has 2 main modules, namely: (1) Trace-Collection Module (2) Positioning Module

(1) Trace-Collection Module: This module works during the user's walking trip to generate the reference trace. The trace will pass some access points and also collect data.

(2) Positioning Module: This module also uses user's data from sensors. It will also get information from BLE access points to modify the trace and increase the accuracy.

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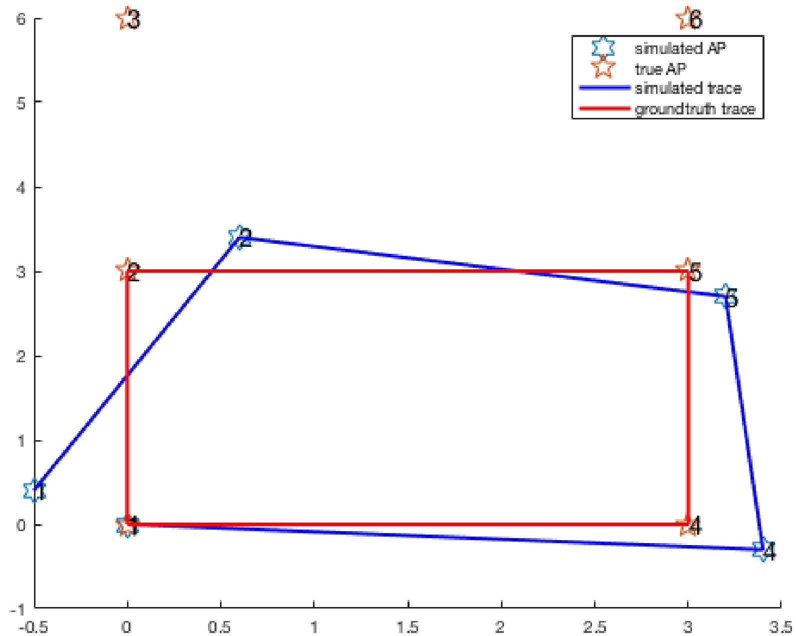
PART TRREE

Algorithm Design

Optimization On Enclosed Traces



Here is an example of an enclosed trace: if one user chose the path from 1-4-5-2-1, the ground-truth trace is like the red line one. However, when we use sensor to detect it, there will be some errors like the blue one. So the same "1" are not enclosed which give us possibility to optimize

Walking Progress Estimation

Algorithm 1: Optimization On Enclosed Traces

Input: $GLG, UserTrace$

Output: $ModifiedUserTrace$

n = Numberof(AP in $UserTrace$);

for $j = 1; j \leq n; j++$ **do**

    $flag = true$;

    $(x, y)_{Global(j+1)}$=Coordinates in GLG;

    while $flag$ **do**

        Adjust $(x, y)_{Local(j+1)}$;

        if *argmin* $(x, y)_{j+1} = (x, y)_1 - (x, y)_n$ **then**

            $flag = false$;

    $(x, y)_{Local(j+1)} = (x, y)_{Global(j+1)}$;

Connect $(x, y)_{Local}$ form $ModifiedUserTrace$;

return $ModifiedUserTrace$;

Step Detection

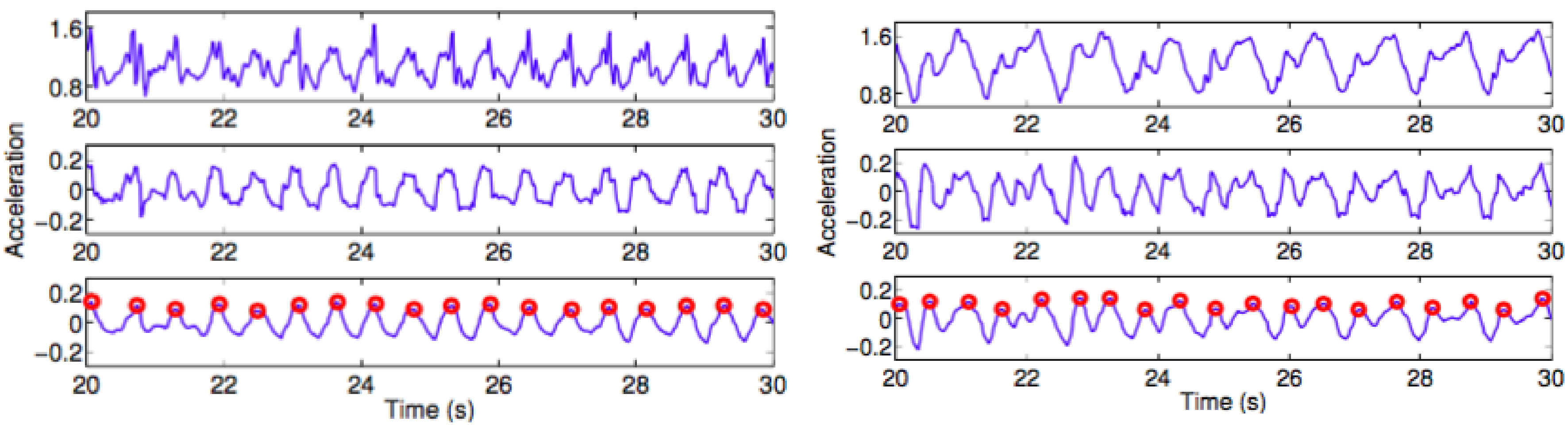
FOLLOWME recognizes user steps based on the accelerometer readings. Since the maximum amplitudes along all 3 axis of the accelerometer occur when the heel strikes the ground, they devise a peak recognition algorithm to detect these strikes/steps.

To make the step detection independent of the phone's orientation, only the magnitude of the 3-axis acceleration reading

$$\sqrt{(a_x^2 + a_y^2 + a_z^2)}$$

Step Detection

In both figures, the first row displays the original acceleration output from the smartphone, and the smoothed acceleration data and the corresponding low-band component are shown in the second and third rows, respectively. Recognized peaks are highlighted in the third row in red dots. In the figure step detection algorithm is shown to perform well even when the user swings his arm with the phone in hand.



(a) Hold smartphone horizontally. (b) Hold smartphone in hands.

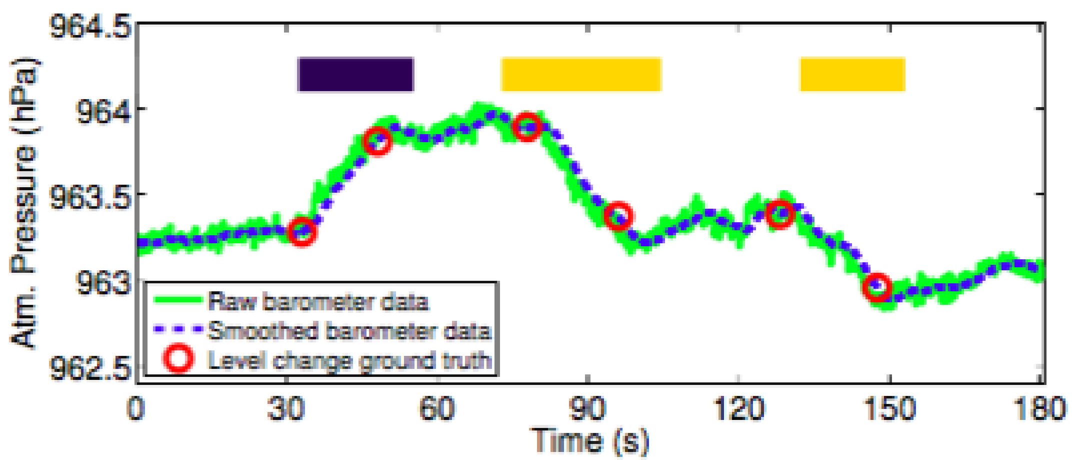
Turn Detection

The rotation axis of the body during a turn is always directed toward the center of the Earth (i.e., in the direction of gravity).

First determine the attitude of the smartphone using the value of gravity on 3 axis of the accelerometer on the phone's body frame, and then transform the angular velocity from the body frame to the LVLH(local vertical, local horizontal) frame to determine turns.

Level Detection

Due to its low power and excellent relative accuracy, a barometer is adopted in FOLLOWME for level-change detection.



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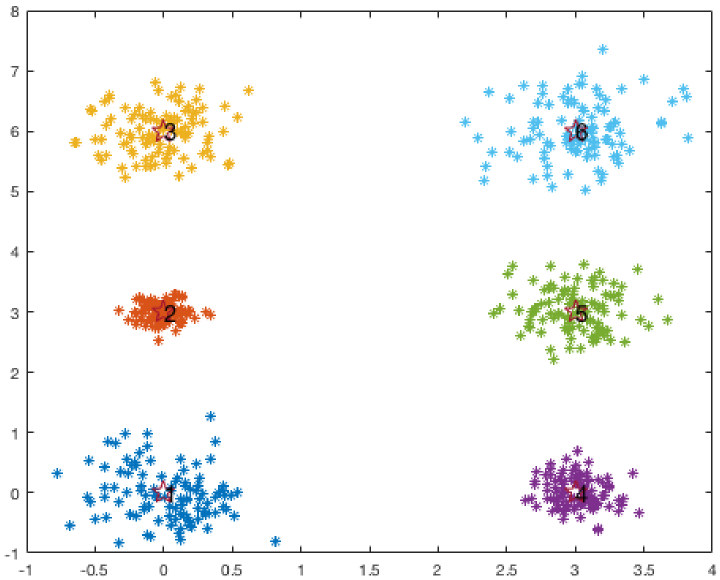
PART FOUR

Evaluation and Analysis



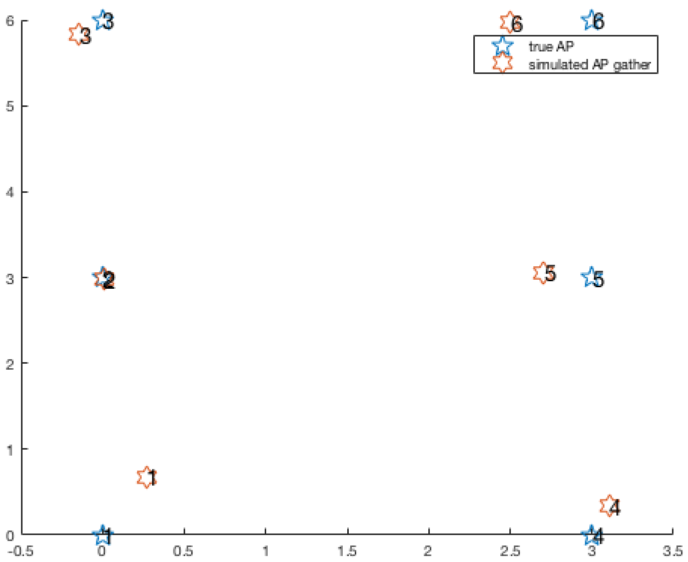


TABLE I
WEIGHTS & NUMBERS OF EACH ACCESS POINT LOCATION

MAC	1	2	3	4	5	6
Number	26	30	22	19	30	21
Weight	13.3055	106.6153	83.5447	55.6379	58.6071	14.4855

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PART FIVE

Future Work

We will soon deploy the BLE access points in our laboratory in the next week. I am responsible for building up the database in the server and using cloud computing to realize the algorithms above.

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Thank you!

Q&A