Navix: Smartphone Multi-sensor, Radio and Probability Map Based Indoor Positioning

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ABSTRACT

Indoor spaces have become the next frontier for location aware applications used in retail, education, events, home electronics and shopping, among others.

In this work, WiFi beacons are deployed in two levels in a testbed indoor environment using fingerprinting and tri-lateration signal-based positioning methods in order to evaluate the results on different densities of beacon arrays and positioning methods. The positioning estimate obtained from the signal-based method is then integrated with smartphone sensors PDR (Pedestrian Dead Reckoning), probability map based on pedestrians tracked location and map information of the indoor environment (e.g. walls and obstacles).

These positioning methods have been implemented in a smartphone application to evaluate their performance in the first and second floor in the ITESM Technology Park.

Evaluations verified that the use of WiFi radio beacons distributions placing one beacon on each 100 square meters provide a robust positioning estimate for hybrid positioning systems and optimizes the number of beacons used to deliver room accuracy (2.11 meters after 2,500 travelled distance) in smartphone based indoor positioning systems.

Keywords

Indoor localization, WiFi localization, dead reckoning, map-matching, probability map, sensor fusion, bayes filters, particle filter, OpenStreetMap, VGI communities

In this work, WiFi beacons are deployed in a test indoor environment in the ITESM Technology Park in Queretaro, Mexico, in order to test the two main used RSSI signal indoor positioning algorithms, which are Location Fingerprinting (LF) Zampella et. al [1] and Tri-lateration, for this purpose the Weighted Centroid Tri-lateration method (WC) is implemented and tested, This algorithm is used by Konrad and Woelfel [2] to find the position of WiFi access points in unknown indoor environments without previous knowledge of the infrastructure.

1. SYSTEM DESIGN AND IMPLEMENTATION

The localization solution approach integrates estimates from all the available sources of information. PDR and signal-based positioning, in the from of WiFi position estimate. The WiFi weighted centroid algorithm is selected due to its simplicity and low computational resources, given that a scattered and dense access points distribution is available, this method is able to estimate a good position state observation. The algorithm derives the position by calculating the centroid of a polygon formed by connecting the position beacons in Line Of Sight (LOS), described and implemented in previous work ([3], [4]).

The map database is considered to improve the knowledge of the indoor environment, a map xml-like structure using the OpenStreepMap geo-markup description. This map structure including layered data and represented as a graph node-link model, offers the possibility to add all kind of information to the map structure, as position of beacons, walls and nodes to create a probability map.

A probability framework using Bayes filters is selected, due to if offers a probabilistic framework to represent the user position state, observation and environment knowledge. A Particle Filter (PF) is used to fuse the PDR and WiFi positioning, while weights assigned to each particle include information from the map database and the generated probability map.

The positioning solution includes the following features:

- Hybrid position estimates from PDR and signal-based WiFi positiong
- Map database of the indoor environment in a graph node-link representation layered with relevant data of

elements in the building, as access points, beacons, reference points, nodes to construct the probability map, walls, doors, staircases, elevators, etc

- Probability map generated using node-link model, by assigning Gaussian distributions centered in the node and applying a Gaussian Mixture Model to generate the probability distribution
- Bayes filter implementation used for data fusion. Particle filter used to provide position estimates from the mentioned sources of positioning information

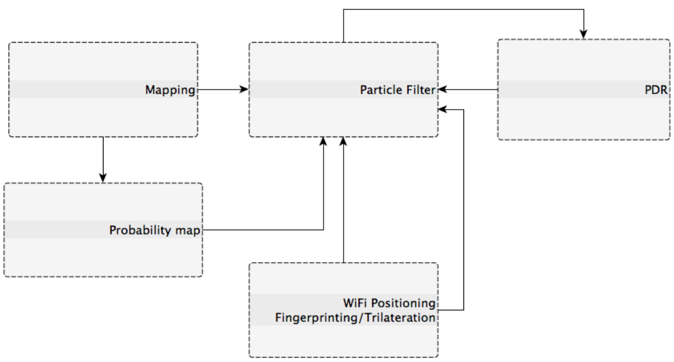

Figure 1: Block diagram for the localization solution

2. RESULTS

The accuracy is evaluated by measuring the Euclidean from the calculated positions, recorded during the tests, to reference points marked in the test scenario.

The WC method provides room-level accuracy required for indoor location applications when the reference nodes distribution is proper as shown in this work, while the accuracy is improved when this technique is fused with other smartphone sensors and map layout information in a Bayesian Framework as implemented in [4].

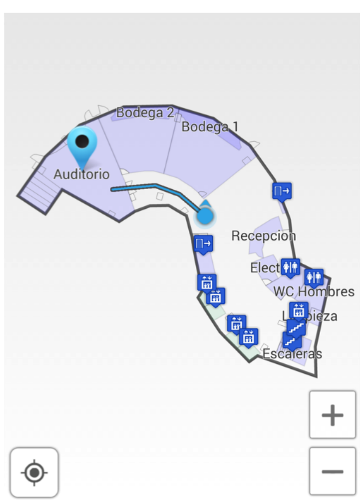

Figure 2: Fingerprinting localization method in the smartphone implementation

Method	Average error (m)	Lap
Fingerprinting (LF)	3.47	12
Tri-lateration (WC)	3.93	12
Hybrid Tri-lateration (WC + H)	2.11	12

Table 1: Results for the experimental evaluation of the implemented localization methods

Table 1 presents the results for the experimental evaluation. The average error and the travelled distance are mentioned, where each lap is equal to 209 meters, in order to compare the accuracy achieved by each of the implemented methods using different technologies and techniques for positioning.

The best accuracy is estimated by the combination of PDR, WiFi and probability map derived from the users most visited locations, which is 2.11 meters in average. The position is estimated below 5 meters 98 % of the time, while for Fingerprinting and LF the error accuracy is about 3.5 and 4 meters and the estimated position is 95% of the time below 6 meters accuracy.

3. CONCLUSIONS

The solution described in this work uses the hardware components present in modern smartphones to provide a hybrid indoor localization approach. Accelerometer, compass and gyroscope are used to track the device movement and calculate a relative position using the PDR (Pedestrian Dead Reckoning) algorithm. In the first stage the solution calculates the position of the user from the previous position, but due to the sensors noise and modeling errors, in a second stage, the estimation is corrected by WiFi positioning observations and previous knowledge of the indoor environment.

An indoor position application which uses a smartphone as a measurement device and the indoor OSM tagging schema to provide information about the indoor environment shows a promising approach for future smartphone based indoor navigation applications.

4. REFERENCES

[1] F. Zampella, A. R. Jimenez, and F. Seco, “Robust indoor positioning fusing pdr and rf technologies: The rfid and uwb case,” October 2013.

[2] P. W. Thomas Konrad, “Wifi compass wifi access point localization with android devices,” Master Thesis, Information Security program at St. Pölten University of Applied Sciences, May 2012.

[3] J. C. Aguilar, “Personal indoor localization using smartphone multi-sensing, probability map and floor-plan layout information,” Bonn-Rhein-Sieg University of Applied Science, Tech. Rep., December 2013.

[4] J. Aguilar, A. Hinkenjann, P. Ploeger, and J. Maiero, “Robust indoor localization using optimal fusion filter for sensors and map layout information,” *International Conference on Indoor Positioning and Indoor Navigation (IPIN)*, October 2013.