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

J. C. Aguilar Herrera  
University of Applied Science  
Bonn-Rhein-Sieg  
Department of Computer Science  
Sankt Augustin, Germany  
jose.aguilar@smail.inf.hbrs.de

M. Flores  
Navix Indoor Navigation Research And Development  
Queretaro, Mexico  
contacto@indoornavix.com

A. Ramos  
Navix Indoor Navigation Research And Development  
Queretaro, Mexico  
alfredo@indoornavix.com

ABSTRACT
Position awareness in unknown and large indoor spaces represents a great advantage for people, everyday pedestrians have to search for specific places, products and services. Therefore a localization system can greatly improve location aware applications in commercial smartphones. In this work we present Navix, a localization application able to provide the position of the user. The position estimate uses data from smartphone built-in sensors, WiFi (Wireless Fidelity) adapter and map information of the indoor environment (e.g. walls and obstacles). A probability map derived from statistical information of the users tracked location over a period of time in the test scenario is generated and embedded in a map graph, in order to correct and combine the position estimates under a Bayesian representation. PDR (Pedestrian Dead Reckoning), beacon-based Weighted Centroid position estimates, map information obtained from building OpenStreetMap XML representation and probability map users path density are combined using a Particle Filter and implemented in a smartphone application. Based on evaluations, this work verifies that the use of smartphone hardware components, map data and its semantic information represented in the form of a OpenStreetMap structure provide 2.48 meters average error after 1,700 travelled meters and a scalable indoor positioning solution.

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 Particle Filter algorithm used to combine various sources of information, its radio WiFi-based observation, probability particle weighting process and the mapping approach allowing the inclusion of new indoor environments knowledge show a promising approach for an extensible indoor navigation system.

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

In this work, a Pedestrian Dead Reckoning (PDR) algorithm, deriving the travelled distance from the smartphone built-in accelerometer raw data and the heading from the compass and gyroscope data, is used to estimate continuous localization. As each technique has advantages and disadvantages, several sources of positioning information are used to overcome the drift error increasing over time when using the PDR method. WiFi readings data, PDR, map layout information and probability map representing users most visited locations are fused under a Bayesian probabilistic framework.

The positioning solution includes the following features:

- Hybrid position estimates from PDR and signal-based WiFi positioning
- 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
### Table 1: Results for the experimental evaluation of the implemented localization methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Average error (m)</th>
<th>Laps</th>
</tr>
</thead>
<tbody>
<tr>
<td>PDR + WiFi</td>
<td>5.2</td>
<td>3</td>
</tr>
<tr>
<td>PDR + ProbMap</td>
<td>9.1</td>
<td>7</td>
</tr>
<tr>
<td>PDR + WiFi + ProbMap</td>
<td>2.48</td>
<td>7</td>
</tr>
</tbody>
</table>

### 1.1 Design

The smartphone application implemented in Android OS provides an activity where the user can select the localization method to use (from PDR and WiFi positioning).

![Block diagram for the localization solution](image)

**Figure 1: Block diagram for the localization solution**

### 2. RESULTS

**Figure 2: Evaluation of the combination of PDR and WiFi weighted centroid after 5 roundtrips**

Table 1 presents the results for the experimental evaluation. The average error and the travelled distance are mentioned, where each lap is equal to 242 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 2.48 meters in average. The position is estimated below 5 meters 98 % of the time, while for PDR and WiFi error accuracy is about 5.2 meters and the estimated position is 82 % of the time below 6 meters accuracy. While the PDR and probability map offers the worst performance due to the drift in the PDR method, showing that this kind of positioning method needs drift correction from an absolute positioning method, even when using the probability map.

### 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.

A beforehand created floor plan of the building is created in an xml-osm representation from a 2D image of the map in the test scenario. Different components of the building are tagged in order to use this information to improve the position estimation. Indoor OpenStreetMap (OSM) is used to construct a graph representing the knowledge from the indoor environment, it uses key-value pairs as nodes, relations, ways and closed ways to represent corridors, rooms and points of interest in the indoor environment.

The probability map of the indoor environment is generated by monitoring the most visited locations in the indoor environment, as this process in done by empirical observation, it is depend on the subject. A more accurate approach to generate a probability map of most likely user locations could be done by monitoring the user locations for a period of time (e.g. 4 hours) and using this information to generate a heat map indicating the probability of being on each location.

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


