# A Hidden Markov model for indoor tracking Based on Bluetooth fingerprinting and Grid filtering

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## Extended Abstract

With the popularization of smartphone and the development of mobile internet, people's demand on location-based services has increased. Indoors, users are often repeating the same movements, such as walking between main door, office, rest rooms. As a result, massive of pedestrian tracks have been produced. Fingerprint location algorithm based on Wi-Fi or Bluetooth is a popular method in indoor locating. However, this method has many weaknesses including unsteadiness and low robustness, because it generally uses the mean value and its variance of single point Rssi to locate. Grid filters the incorrect positions returned from indoor. Localization, especially under signal fluctuation or fingerprint ambiguity. The Hidden Markov model and Grid filtering of this approach would achieve a higher position accuracy and efficiency. Map information is often available and may contribute to location filtering. Recently, a number of researchers take the position sequence information into consideration. Xiaoguang(2014) had found a fine-grained walk pattern of indoor pedestrians the reliability of the reports. Zhou(2014) had proposed activity sequence based indoor pedestrian localization using smartphones. Zhang(2015) proposed a wireless positioning method based on Deep Learning arm to deal with the variant and unpredictable wireless signals. Jimmy(2013) proposed directional HMM algorithm which can learn user habits and improve the accuracy of indoor localization system. However, the HMM models are trained with the trajectory and the HMM indoor position algorithm relays on the correct and certain data(He, S., & Chan 2015). Borriello(2003) proposed Bayesian Filtering which include the grid filtering to estimate the position. But the HMM model still cannot deal well with the ambiguities resulting and bring the amount of calculation. Therefore, a key challenge here is how to deal with the ambiguities resulting from fingerprinting and the data fusion of big spatial data and limited topology information.

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To solve this problem, we propose an indoor fingerprint positioning method based on the combination of grid filtering and hidden Markov model. This method includes both offline and real time positioning stages. Firstly, during the on-line phase, we firstly divide the indoor space as the grid evenly, and then build accessibility gird based on the local position and set the execution rate. The confidence level of obstacles (or barriers) is set as 0. For obtaining the probability of other positions, we use the historical mobile transition probability, and build an offline estimating range. Secondly, we establish station probabilities based on the nearest neighbor location fingerprint algorithm and grid filtering. During the offline stage, we use mobile signal to get the data and remove noises with Kalman filter, and then store the data into our fingerprint database. While starting on-line locating, this method will judge if it's the first time to locate. The nearest neighbor algorithm will be used for locating if it is the initial point, if not, the prediction database, built according to the location of the former point, will provide a constrained positioning area, and then match the data with fingerprint database to find the closest position. The indoor positioning coordinates can be got based on the nearest neighbor location fingerprint. Thirdly, algorithm then the probabilistic model is constructed. In order to achieve more accurate moving probability model, The prediction accuracy of Hidden Markov model is greatly improved by adding the constraints of grid filtering and updating the database which rule out the influence on the historical data of pedestrian. So, the best pedestrian route is found and the fingerprint based positioning algorithm is modified. The method proposed by this paper can greatly improve the positioning accuracy and stability of pedestrians in the room, verifying the effectiveness of the proposed method. The work results show the improvement on localization accuracy in coping with the turbulent wireless signals.

An experiment in Nanjing normal university used this method and the experiment area is a 15M*10M laboratory room. The presented HMM can deal with ambiguities resulting from Bluetooth fingerprinting. The algorithm is computationally efficient because of the update of the HMM and Grid filtering, based on the positions of Bluetooth fingerprint and grid filtering. Through mining spatial temporal distribution regularities of tracing points, and inputting time orders and appearance probabilities into fingerprint database, the tracing effect of this new method is significantly increased compared to fingerprint positioning algorithm without considering indoor pedestrian tracks. The comparison of two algorithm result is below.

| Method | Area | Accuracy/m | Time/s |
|---|---|---|---|
| KNN | n | 2.95 | 3.1s |
| KNN+HMM+GRID | 3-9 | 2.15 | 1.1 |

**Table 1.** comparison of evaluation index

The location results achieved 2.15m precision more precise than the k-Nearest Neighbor fingerprinting approach. The experiment proved the improvement of accuracy and stability on indoor location. Also, being verified its effectiveness this method can be used in providing route proposal and navigation in shopping mall, museum and airport.

## Reference

Niu, X., Li, M., Cui, X., Liu, J., Liu, S., & Chowdhury, K. R. (2014). Wtrack: hmm-based walk pattern recognition and indoor pedestrian tracking using phone inertial sensors. Personal & Ubiquitous Computing,18(8), 1901-1915.

Zhou, B., Li, Q, Mao, Q, Tu, W & Zhang, X. (2014). Activity sequence-based indoor pedestrian localization using smartphones. IEEE Transactions on Human-Machine Systems, 45(5), 562-574. Zhang, W., Liu, K., Zhang, W., Zhang, Y., & Gu, J. (2016). Deep neural networks for wireless localization in indoor and outdoor environments.Neurocomputing, 194(C), 279-287.

Nielsen, J. J., Amiot, N., & Madsen, T. K. (2013). Directional hidden markov model for indoor tracking of mobile users and realistic case study. Vde Verlag Gmbh, 1 - 6.

He, S, & Chan,S.H.G.(2015). Wi-fi fingerprint-based indoor positioning: recent advances and comparisons. IEEE Communications Surveys & Tutorials, 18(1), 1-1.

Fox, D, Hightower, J, Liao, L, Schulz & Borriello, G. (2003). Bayesian filtering for location estimation. Pervasive Computing IEEE,2(3), 24-33.