Improved Fingerprinting based Indoor Positioning System with Hybrid Sensor Fusion to Overcome the Practical Hinderance

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Abstract: Indoor tracking has evolved with various methods, and the most popularly used method is using signal strength measuring techniques like trilateration, triangulation, and fingerprinting, etc. Out of all the popular techniques, the Wi-Fi fingerprinting method to localize users has been attracting much attention because it doesn’t require any line-of-sight. The offline phase takes into account of LOS or any permanent hindrances to the access point radio signal during the recording of the Fingerprinting dataset. In the online phase by comparing the RSSI values and using KNN /WKNN can detect the location of one’s position in indoor where the GPS signals can’t be reached. The offline phase requires much more effort to capture RSSI values, and any change in the environment or location of the Wi-Fi access point requires all the calibration in offline need to repeat, which is tedious. Even a temporary moving block like humans/doors/new construction will affect the accuracy of positioning in the online phase. The proposed algorithm detects the affected Wi-Fi nodes hindered by blocks and eliminates those during the online comparison phase, so then improves the accuracy. This algorithm also is useful in identifying the block is permanent or temporary to optimize the retake of the offline phase. The experimental result shows that the proposed hybrid sensor fused method improves the position estimation over the Fingerprinting method.

Keywords: Dead reckoning, Fingerprinting, indoors positioning, localization, Wi-Fi positioning.

I. INTRODUCTION

In today’s world, the smartphone-based indoor positioning technic has an enormous amount of applications benefiting from location detection, Hospital routing, food delivery, travel booking, personalized ads, emergency evacuation management, inhouse stock navigation, etc. Wi-Fi/Bluetooth based received signal strength measuring technic of the indoor positioning system is popular among other methods. Because of the variation of signals, a Wi-Fi/Bluetooth based positioning system tends to have fluctuations and errors due to Line of sight [1] and influenced by non-moving blocks and moving obstacles like doors, furniture, new constructions, etc. Also, the method might also fail at a random fraction of time due to signal unavailability.

The most typically carried out approach in RSSI-based localization is the Wi-Fi/Bluetooth fingerprinting. Wi-Fi/Bluetooth signal based positioning is popular because of the practical feasibility of placement of access point devices, use of already available access point infrastructures, and usage of the already existing sensor with the smartphone. The proposed method computes the current location by comprises of the trajectory of a mobile device for a short range between last known locations. It is using inertial navigation and detecting all the Wi-Fi nodes that are erroneous and fetch the subset of comparison fingerprint data to be comparing for the location. This method recommends when the update of the fingerprint database is required due to the permanent change in the indoor environment.

II. RELATED WORK

The wide used fingerprint technic has an advantage over any other Wi-Fi-based positioning system. The fingerprinting-based positioning system doesn’t get affected with Line of sight or everlasting block on account that it’s identical as the records collection phase; it has an error vary of 1 to 3m [2] under the normal condition without any hindrance of the access points. But the accuracy of the Fingerprinting technic is affected by any new hindrance like new constructions, moment or addition of furniture, moving blocks, and even human present [3,4,5]. in the fingerprinted environment would need for a re-training phase, which is tedious [2]. Non-permanent hindrance or any human intervention [4]. It can’t be accounted for in the training phase at all, and it has to be tackled during the fingerprinting matching algorithm. Wi-Fi sign fingerprint-based technic required the place & access point not be altered from the recording/training segment to the proper position phase [6]. The fingerprinting technic has a drifting error [7], which happens due to the Wi-Fi signal fluctuations at random due to multipath consequences extensively mission the precision of place estimation [5] and the preservation of a legitimate radio map [4]. Location map conscious position and fusing of the inertial sensor [9] is used to overcome this venture in a realistic environment. None of the strategies mentioned had been able to discover the root cause, which is the affected anomaly node. If we can find the nodes, which get affected by using the practical hindrance and keep away from in the course of the location estimate, the system accuracy can be accelerated.

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III. WI-FI FINGERPRINTING BASED POSITIONING TECHNIQUES

Wi-Fi Fingerprinting Method [2] has advantages over any other signal measuring-based positioning method since it takes into account of blocks while doing the training phase of fingerprinting and does not depend on the Line of sight of the signal from the access point. The fingerprinting approach calls for guide series recording of the enormous dataset in the offline recording phase (which is also called a training phase), and this has to be pre-processed [2]. Moreover, when there’s a change with the environment, the fingerprinting method calls for a re-training process to handle the change. [2] Wi-Fi fingerprinting based positioning estimation algorithms to consist of two phases, offline phase (training phase) and online (position estimate phase), as Fig. 2. depicts. But here it requires a substantial additional exertion to capture RSSI values and in an online phase access point search for the already recorded dataset and saved values to estimation the position of the target node. And, if any Wi-Fi access point location bought changed, need to rehash the training phase, which is tedious.

![Fig. 1. Wi-Fi Fingerprinting procedure for positioning estimation](image)

The main drawback of fingerprinting based system is any permanent or temporary modifications of the environment together with including or removing furniture/buildings, doors, human hindrance in the surrounding of location measuring point will affect the accuracy of the location estimate and may requiring redoing the offline phase again to update the fingerprint dataset. Furthermore, it’s challenging to detect it’s a temporary or everlasting intervening of fingerprinting.

IV. DEAD RECKONING (DR) BASED POSITION - USING SMARTPHONE INERTIAL SENSOR FOR POSITIONING

In indoor where enough numbers of access point indicators are no longer accessible is a dead zone. In such locations in indoor RSSI based location methods will no longer work.

In the dead zone, Wi-Fi indoor positioning algorithm’s last known position is used with the DR system [13] to estimate the position of the target device position indoor. DR system computes the location by utilizing the inertial sensors [7] (like magnetometer, accelerometer/gyroscope/step counter sensor) of the mobile device, as shown in Fig.2.

![Fig. 2. Position estimation by Dead Reckoning method](image)

The walked distance (D) from the last known position is estimated by

\[ D = \text{number-of-steps-counted} \times \text{Step-length-estimated} \]  

(1)

Where, number-of-steps-counted indicate the number of steps walked determined with the aid of accelerometer/step counter, and the step-length-estimated denotes the length of every step walked, which can be computed by using counting the wide variety of steps walked in a route by using the person to traverse a exact distance [12].

The course of the person moved is decided via the inertial sensor magnetometer/Compass. The current location the usage of the DR approach is estimated the use of the distance moved D, and the direction in which the user traveled. But the drawback is here DR presents good accuracy solely for short-range. If the fluctuations of the RSSI values are high, even DR can’t produce the exact location because of the last known position from any Wi-Fi-based positioning algorithm. so, to get excessive accuracy anomaly nodes must have been identified and eliminated while computing the LKP (last known position) earlier than feeding the PDR system.

V. THE PROPOSED HYBRID SOLUTION

The proposed method to eliminate the access points affected by the practical hindrance by any temporary or new blocks and used the remaining list of scanned access point radio signal to match with fingerprinting dataset using the matching algorithm. In this method, during the off-line phase, the access point location and Euclidean distance (ED) of the access point from the recorded position are recorded along with the radio map fingerprinting dataset. The proposed system additionally does sensor fusion with available sensors from the smartphone. The DR technique makes use of the following sensor in the smartphone where used Wi-Fi radio signal receiver, magnetometer (for direction), Accelerometer (for step detection), Gyroscope (for the position of a smartphone). Algorithm 1. Sensor fusion with fingerprinting to overcome practical hindrance

1. Off-Line phase: Recording of Fingerprinting dataset along with the Access point location and Euclidean distance of access point from the recorded position.
2. Scan all the Access point at the current position S_{AP} (AP_1, AP_2, ..., AP_n)
3: Compute the current position using the DR method (using inertial sensor & LKP), \((X_{\text{DR}}, Y_{\text{DR}})\)

4: Compute the Euclidean distance of the access point from the DR method estimated position.
\((ED_{AP1}, ED_{AP2}, \ldots, ED_{APn})\)

5: Online phase: Fetch the fingerprint data for the DR method estimated position using the matching algorithm

6: For each \(ED_{AP} \in ED_{AP}(i, n)\)

7: Compare the Euclidean distance of DR and Euclidean distance of the access point for the location recorded in the offline.

8: if \(ED_{AP}\) capture in off-line phase > \(ED_{AP}\) computed using DR method \(M\) Mean distance error.

9: Access point affect by practical loss and remove from the scanned list \(S_{AP}\)

10: Compute the current position using the new \(S_{AP}\) comparing it with the fingerprinting dataset using the matching algorithm.

Where, \(S_{AP}\) is the scanned Access point list \((\text{AP}_1, \text{AP}_2, \ldots, \text{AP}_n)\), \(ED_{AP}\) is the Euclidean distance between the estimated location and the access point.

The Algorithm continuously estimates the current position using the DR method and compute the list of Euclidean distance (ED) from the current position to the access point. The access point locations stored during the off-line phase are used to compute the ED. Then the algorithm compares the Euclidean distance of DR and Euclidean distance of access point for the location recorded in the offline, if ED capture in off-line phase is greater than the sum of ED computed using DR method and Mean distance error of DR, the access point is identified as the signal hindrance by human or new blocks. The identified access point is removed from the scan list of the access point and then compared with the fingerprinting dataset using the matching algorithm to estimate the current position. The proposed algorithm performs better than both the methods Wi-Fi Fingerprinting method [16] and the DR method.

VI. EXPERIMENT SETUP AND RESULT

Figure 3. (A) shows the experimental setup of our test lab environment. The test lab environment measure 38.2 M 65.8 meters width and the Wi-Fi fingerprint [15] matric is created using the offline phase across the floor with a displacement of every 4 meters. The experiment is conducted to find the current location of the mobile device at various positions inside the test lab environment using the fingerprinting technic and using the proposed hybrid fingerprinting fused method. There was human’s hindrance in the test lab environment, which affect the Wi-Fi access point radio signal.

![Fig. 3. (A) The floor plane of the test lab exhibition along with the placement of the Fingerprinting position. (B) The heatmap of the distance error of the proposed method](image)

In a location estimate system, the distance error denotes the error in positioning, which is the difference between the estimated position \((X_{\text{estimated}}, Y_{\text{estimated}})\) and the actual position \((X_{\text{actual}}, Y_{\text{actual}})\)

\[
\text{Distance Error} = |\text{Actual position} - \text{Estimated position}|
\]

(2)

\[
\text{Distance Error} = \sqrt{(X_{\text{estimated}} - X_{\text{actual}})^2 + (Y_{\text{estimated}} - Y_{\text{actual}})^2}
\]

(3)

The average distance error is computed by averaging the distance errors for all the locations along the moving trajectory.

Table- 1: Mean distance error (m) VS No. of Hindrance APs

<table>
<thead>
<tr>
<th>No. of Hindrance APs</th>
<th>Mean distance error (m)</th>
<th>The proposed method</th>
<th>Fingerprinting method</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Path 1</td>
<td>Path 2</td>
<td>Path 1</td>
</tr>
<tr>
<td>1</td>
<td>2.64</td>
<td>2.56</td>
<td>6.54</td>
</tr>
<tr>
<td>2</td>
<td>3.21</td>
<td>3.02</td>
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</tr>
<tr>
<td>3</td>
<td>4.12</td>
<td>4.01</td>
<td>11.02</td>
</tr>
</tbody>
</table>

The fingerprinting position estimation [16] has a mean distance error in the range of 10 to 20 meters doing to the temporary hindrance of few access point signals, whereas the proposed method has only the mean distance error in the range of 2 meters to 5 meters. The fig. 3. B shows the heatmap of the distance error of the proposed method, which showcases the efficiency of the system. The proposed method able to estimate the reference position using the DR method, calculate the Euclidean distance of the scanned access point and removes any access point whose value is greater than the actual distance during the recording of the offline phase. The method also fetches only the neighborhood fingerprinting dataset to matching to closest fingerprint from the subset of the neighborhood fingerprinting. The position error increases proportionately with the increase of hindrance of access point signal by any new blocks as shown in the Table- 1.

The proposed method, we can identify the change in environment is temporary (like human passing the access point) or permanent (like new construction or access point location change etc.) by recording the identification and monitoring over a period to make a rule-based decision to improve the efficiency of redoing the off-line phase.
VII. CONCLUSION

Indoor location service is essential and helpful in locating one’s position inside a building. Wi-Fi fingerprinting based positioning techniques are much more popular due to the coverage area, easy to implement, and wide availability. But the Fingerprinting method produces high distance error in the presence of new permanent or temporary hindrance. The proposed method identified the access point affected by the hindrance and eliminated in the Fingerprinting matching algorithm to estimate the current position and increase the position accuracy.

REFERENCES


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Bhulakshmi Bonthu is a Professor at VIT University with 11 years of professional experience working with VIT in School of computer science department since 2009. She has completed M.Tech from IIT Madras, India. Her research interest includes indoor positioning & tracking system, wireless sensor, and mobile technology. Her research on indoor positioning was sponsored by Natural Resources Data Management System (NRDMS, Government of India).

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