A Novel Access Point Selection Strategy for Indoor Location with Wi-Fi

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Abstract: The increasing demands on the indoor location service inspire the wide attentions to investigate the indoor position algorithms. Access point (AP) selection is critical important for increasing the estimation accuracy of the indoor location. In this paper, the key features in influencing the accuracy of indoor location systems are investigated. Base on the analysis results, we present an AP selection strategy for indoor location by proposing a novel AP selection index for test point. By using the experiment data, the K-Nearest Neighbor (KNN) and weighted-KNN (WKNN) indoor location methods are carried out to illustrate the performance proposed AP selection strategy. The performance of our AP selection strategy is validated by comparing with the exhaustive AP selection strategy, the fisher AP selection strategy and the largest RSSI strength AP selection strategy. The experiment results show that the proposed AP selection strategy can improve the location accuracy of indoor location with Wi-Fi.

Key Words: Indoor location; Access point selection strategy; Wi-Fi, location accuracy

1 INTRODUCTION

The development of location technology has become an important add-on to many existing location service systems. GPS technology has taken most of the outdoor location tasks. However, it fails to repeat this success indoors [1]. Mobile devices are associated with wireless network technologies that have the potential to provide user location and context cues to the services they offer. Wireless sensor network (WSN) such as ZigBee, Radio Frequency Identification (RFID) and Wi-Fi can be deployed with localization capability. The location service can be applied for localization and tracking of object or people in health care applications [2]. Different kind of indoor location technologies have been investigated in recent years [3-6].

In [3], the author studied a type of indoor positioning systems called location fingerprint technique that utilized received signal strength indication (RSSI) of wireless local area network (WLAN) interfaces. Among the existing indoor location technologies, the Wi-Fi based indoor location is widely recognized as a practical and useful tool. A hyperbolic location fingerprinting, which records fingerprints as signal strength ratios between pairs of base stations instead of absolute signal strength values was presented in [4]. In [7], the author presented a location sensing prototype system that used RFID technology for locating objects inside buildings. The major advantage of was that it improves the overall accuracy of locating objects by utilizing the concept of reference tags. In this paper, the location fingerprinting is used to investigate the access point selection strategy.

The conventional approach to AP selection is based on the received signal strength (RSS) measurements from candidate APs. By associating with the AP promising a better channel condition, it serves stations more reliably and is likely to support more sessions due to its preference to higher data rates [6]. However, as system load is often unevenly distributed over operational WLAN [8]. The APs are usually under decentralized control and are managed by a varied set of residents and businesses [9].

AP selection is driven by the physical layer. The selection policy currently used by common operating systems for automatically selecting an AP simply scans for APs and then chooses the one with the highest signal strength [8]. An algorithm known as CaDet for power-efficient location estimation by intelligently selecting the number of Access Points (APs) used for location estimation was presented in [10]. In [11], a decentralized access point selection architecture for wireless LANs was proposed. Moreover, there are many possible algorithms for selecting an AP, which can be regarded as optimal strategies for achieving some objective, although the widely deployed one simply selects AP with strongest signal, as mentioned previously. They can be different in their available information used for selection and their employing objective selection to be maximized or minimized [11]. This paper [12] investigated data analysis of the received signal strength indication.

This article attempts to analysis the key features in influencing the accuracy of indoor location systems. Firstly, the location accuracy with different numbers of APs is studied; Secondly, we investigate the location accuracy with selecting different APs. Finally, based on the anglicising results, a novel AP selection strategy for indoor location with Wi-Fi is presented by taking the advantages of on-line stage and off-line stage. The performance of our AP selection strategy is demonstrated by comparing with the exhaustive AP selection strategy, the fisher AP

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selection strategy and the largest RSS strength AP selection strategy.

The rest of this paper is organized as follows. The indoor location methods are introduced in Section 2. The experiment environment is introduced in Section 3. The key factors are analysed and a novel AP selection strategy is presented in section 4. Simulation results are shown in section 5 and Section 6 concludes this paper.

2 Indoor Location Methods

KNN is one of the most fundamental and simple classification methods and should be one of the first choices for an indoor location when there is little or no prior knowledge about the distribution of the data. For KNN method, the signal strength of the test point is received. Then, find K reference points that are the nearest neighbor. Take the average value of K reference points as the tested coordination [13].

Assume that there are n APs, m reference points assigned in the indoor environment. m position fingerprints are collected in the fingerprint database, which is marked as $R=\left[RSS_1, RSS_2, \cdots, RSS_n\right]$. Each position fingerprint saves the RSSI from all the APs, which is marked as $RSS_i=[RSS_{iAP1}, RSS_{iAP2}, \cdots, RSS_{iAPj}, \cdots RSS_{iAPm}]$, $1 \le i \le m$ where RSS_{iAPj} represents the RSSI stored in the ith reference point received from the jth AP. It first examines the Euclidean distance of the online RSSI measurement vector to the APs in the database, which can be described as [14]:

$$D_i = \left\| r - \overline{\psi}_i \right\| \tag{1}$$

where $\overline{\psi}_i = \frac{1}{T}\sum_{\tau=1}^{T}\psi_{i,1}\left(\tau\right)$ is the average RSSI vector for AP i. Then, the distances are stored in ascending order and the first K APs that have the smallest distances are obtained to estimate the location $\widehat{p}$:

$$\widehat{p} = \frac{1}{K}\sum_{i=1}^{K} p_i \tag{2}$$

To improve the location accuracy, WKNN is further investigated. The calculated distances can be used as weights to estimate the location and it is referred to as the WKNN. The estimated location can be computed by:

$$\hat{p} = \frac{\sum_{i=1}^{K}\frac{1}{D_i}p_i}{\sum_{i=1}^{K}\frac{1}{D_i}} \tag{3}$$

The KNN method (2) and WKNN (3) method are used in the experiment to investigate the location accuracy with different numbers of APs, the relationship between the selection of AP and location accuracy, the effectiveness of the AP selection strategy in the following sections.

3 Experiment Environment

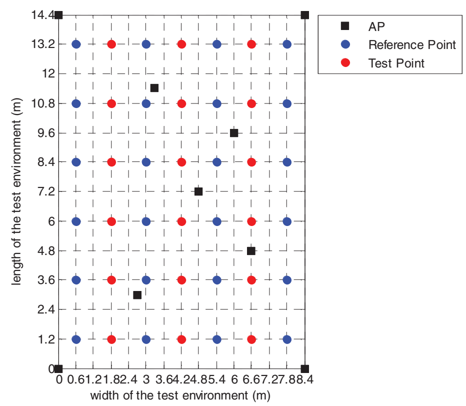

Fig. 1. Schematic diagram of indoor environment

Schematic diagram of indoor environment is shown in Fig. 1. We select a 14.4×8.4 m^2 indoor environment to carry out this experiment. 9 APs are assigned to construct the wireless Wi-Fi network. 24 reference points are used to sample the RSSI and build the fingerprint database. 18 test points are used to examine the location accuracy. To better monitor the practical environment, we use TP-Link router to generate the AP signal. A ThinkPad notebook with wireless network is used to sample the RSSI.

Fig. 2. The interface of RSS data detection and acquisition

We detect the RSSI with a platform developed with C++ program. The interface of RSSI data detection and acquisition is shown in Fig. 2, where SSID represents the different APs information; $irssi$ represents the strength of the corresponding APs. For each reference point, the PC samples the RSSI of all the APs every one second.

4 Novel AP Selection Strategy

In this section, we first investigate the location accuracy with different numbers of APs. Then, AP selection strategy is proposed.

4.1 Location accuracy with different numbers of APs

In an ideal indoor environment, the location accuracy will be improved with more APs are used for positioning. However, the location accuracy could be decreased in the complicated practical environment [9]. At the same time, the more APs are used for positioning, the more computational burden is needed. We investigate the location accuracy with different number of APs in this subsection based on the data sampled in Section 3.

We estimate the location accuracy of the indoor positioning from 1 AP to 9 APs. KNN and WKNN methods are used to estimate the location of the test point. The relationship between the number of AP and indoor location accuracy is shown in Fig. 3.

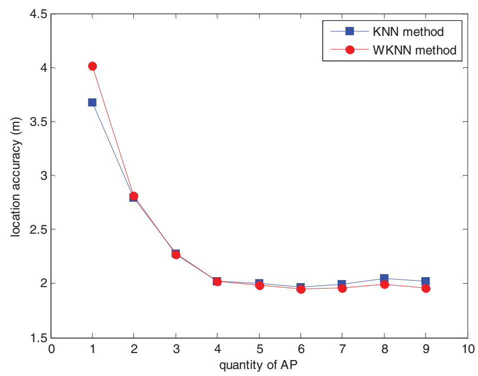

Fig. 3. Relationship between the number of AP and indoor location accuracy

The result shows that, the location accuracy is 1.971m (KNN) or 1.951m (WKNN) if we use 6 APs, which is the best location accuracy for this experiment. However, if we use 4 APs to position, the location accuracy is 2.018m (KNN) or 1.951m (WKNN). We can find that the location accuracy will not increase when the number of the AP increases to 4. The reason is that there are some inaccurate APs for certain test point. These APs will decrease the location accuracy. We can conclude that satisfactory location accuracy is obtained while using 4 APs. This will reduce the computation burden in indoor location.

4.2 AP selection strategy

The goal of AP selection is to select part of the APs that can achieve better performance in indoor location. The computation burden will be reduced and the location accuracy will be increased if an effective AP selection strategy is adopted.

The existing AP selection method selects APs during either the sampling stage or the location stage [8, 13]. Fisher standard based AP selection strategy is usually use in indoor location [15]. At the sampling stage, a relationship index is computed based on the RSSI to select the APs used for location. In the existing wireless LANs, each test point selects the AP with maximum RSS because it can be expected to attain the high-speed transmission rate. It, however, can lead to the concentration of many test points in a few APs because it can happen that many test points are geographically near some specific AP, which is thus very likely to provide the maximum RSS with many test points. This will cause significant degradation of their throughput.

At the location stage, the APs are selected based on the RSSI received from each AP. Thus, the location accuracy will be increased if we select the APs both at location stage and sampling stage. In this paper, we clarify the discrimination for each AP based on the sampled RSS by:

$$D\left(AP_j\right)=\frac{\sqrt{\sum_{i=1}^{m}\left(RSSmean_i^j-\frac{1}{m}\sum_{i=1}^{m}RSSmean_i^j\right)^2}}{\sum_{i=1}^{m}RSSstd_i^j} \tag{4}$$

where $D\left(AP_j\right)$ represents the discrimination of j-th AP; m represents number of the reference points. $RSSmean_i^j$ represents the average value of the RSSI sampled by j-th AP; $RSSstd_i^j$ represents the standard deviation of the RSSI sampled by j-th AP. For j-th AP, the index $D\left(AP_j\right)$ can reflect the ability of discriminating the RSSI.

The discrimination indices for n APs can be described as:

$$D\left(AP\right)=\left[D\left(AP_1\right),D\left(AP_2\right),\cdots,D\left(AP_N\right)\right] \tag{5}$$

At the location stage, the RSSI are described as follows:

$$R=\left[RSS_1,RSS_2,\cdots,RSS_n\right] \tag{6}$$

where RSS_j represents the RSSI sampled by j-th AP.

In this paper, both the AP discrimination index (4) and the strength of the APs (6) are used to select the APs for indoor location. The discrimination index is used as the weighting for the corresponding the RSSI. The AP selection index W is computed by:

$$W=\left[w_1,w_2,\cdots,w_n\right] \tag{7}$$

where $w_j=\frac{D\left(AP_j\right)}{\sum_{j=1}^{m}D\left(AP_j\right)}norRSS_j$ and $norRSS_j$ is the normalization value of RSS.

The computed AP selection index W s are ranked from maximum to minimum. Then, select the first l APs for indoor location.

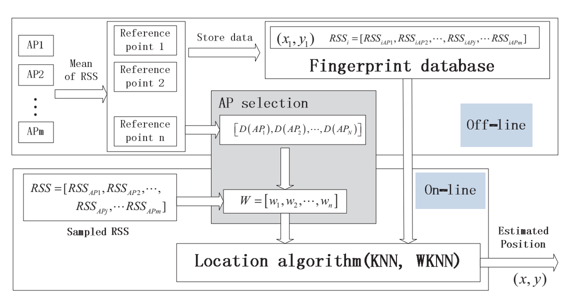

Fig. 4. Structure of the indoor location with AP selection

The structure of the indoor location with AP selection strategy is shown as Fig. 4. The procedures of indoor location include the off-line stage and on-line stage. Our AP selection strategy takes the advantages of both off-line and on-line stages. The discrimination indices for n APs are computed at the RSS sampling stage and the AP selection index W is computed at the locating stage. The location algorithm, such as KNN and WKNN methods, uses the selected APs to indoor location.

5 Experiment Results

In this section, we will show the necessity of AP selection by studying the relationship between the selection of AP and location accuracy. Our AP selection strategy is validated by doing an experiment. The experiment environment is described in Section 3.

Before detailing the location accuracy, we investigate the location accuracy with selecting different APs. Based on the result of Section 4.1, four APs are the most suitable case for indoor location with less computation burden and high location accuracy. Then, we select four APs out of nine APs to test the location accuracy. There are 126 different groups of APs. The relationship between the selection of AP and location accuracy is shown in Fig. 5. The location accuracy under different AP combination is shown in Tab. 1 and AP combination with high location accuracy in Tab. 2.

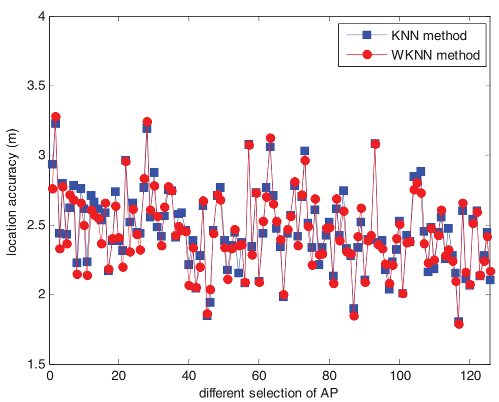

Fig. 5. Relationship between the selection of AP and location accuracy

Table 1. Location accuracy under different AP combination

Methods	KNN method	WKNN method
Best location accuracy (m)	1.805	1.786
Worst location accuracy (m)	3.225	3.278
Average location accuracy (m)	2.466	2.448
Standard deviation of location accuracy (m)	0.281	0.279

Table 2. AP combination with high location accuracy

Methods	KNN method	WKNN method
AP_4, AP_5, AP_8, AP_9	1.805	1.786
AP_1, AP_4, AP_7, AP_9	1.850	1.860
AP_2, AP_5, AP_8, AP_9	1.901	1.845

The results show that the location accuracy with different group of APs is undulant. This means that it is important to select the APs before indoor location.

The performance of our proposed AP selection strategy is investigated by using KNN and WKNN indoor location algorithm. The performance is compared with the exhaustive AP selection strategy, the fisher standard based AP selection method and the largest RSS strength AP selection strategy. The simulation results are shown in Figs. 6-9. The location accuracy under different AP combination is shown in Tab. 3.

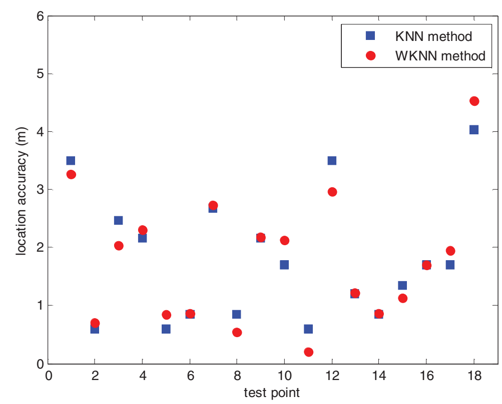

Fig. 6. Location accuracy with the exhaustive AP selection strategy

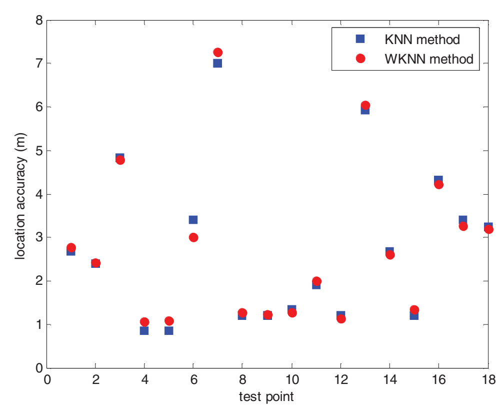

Fig. 7. Location accuracy with the Fisher standard based AP selection strategy

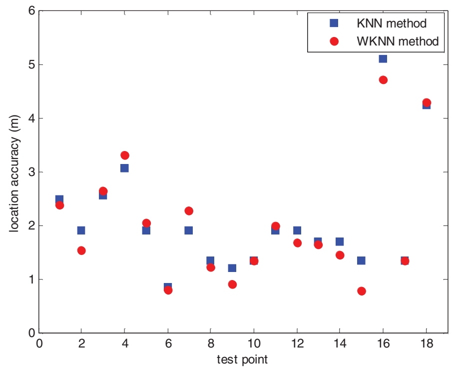

Fig. 8. Location accuracy with the largest RSS strength AP selection strategy

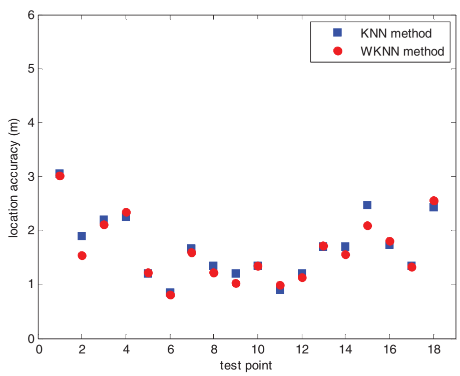

Fig. 9. Location accuracy with the our AP selection strategy

Table 3. Location accuracy under different AP combination

Methods	KNN method	WKNN method
Fisher standard based AP selection strategy (m)	2.757	2.775
the largest RSS strength AP selection strategy (m)	2.095	2.019
our AP selection strategy (m)	1.694	1.634

The results show that the effectiveness with our proposed AP selection strategy can improve the estimation accuracy of indoor location with Wi-Fi. The location accuracy with our proposed AP selection strategy is better than the exhaustive AP selection strategy, the fisher standard based AP selection strategy and the largest RSS strength AP selection strategy.

6 Conclusions

In this paper, the key features in influencing the accuracy of indoor location systems were investigated. Base on the analysis results, an AP selection strategy for indoor location was proposed. By using the experiment data, the KNN and WKNN indoor location methods were carried out to illustrate the performance proposed AP selection strategy. The experiment results showed that the proposed strategy can improve the estimation accuracy of indoor location with Wi-Fi.

References

[1] K. Curran, E. Furey, T. Lunney, J. Santos, D. Woods, and A. McCaughey, An evaluation of indoor location determination technologies, Journal of Location Based Services, vol. 5, pp. 61-78, 2011.

[2] K. Kaemarungsi, R. Ranron, and P. Pongsoon, Study of received signal strength indication in ZigBee location cluster for indoor localization, in Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON), 2013 10th International Conference on, 2013, pp. 1-6.

[3] K. Kaemarungsi, Distribution of WLAN received signal strength indication for indoor location determination, in Wireless Pervasive Computing, 2006 1st International Symposium on, 2006, p. 6 pp.

[4] M. B. Kjærgaard, Indoor location fingerprinting with heterogeneous clients, Pervasive and mobile computing, vol. 7, pp. 31-43, 2011.

[5] X. Wang, J. Shang, F. Yu, and J. Yan, Research on Semantic Location Models for Indoor Location-Based Services, 2013.

[6] W. Wang, S. C. Liew, and V. O. Li, Solutions to performance problems in VoIP over a 802.11 wireless LAN, Vehicular Technology, IEEE Transactions on, vol. 54, pp. 366-384, 2005.

[7] L. M. Ni, Y. Liu, Y. C. Lau, and A. P. Patil, LANDMARC: indoor location sensing using active RFID, Wireless networks, vol. 10, pp. 701-710, 2004.

[8] L. Du, Y. Bai, and L. Chen, Access point selection strategy for large-scale wireless local area networks, in Wireless Communications and Networking Conference, 2007. WCNC 2007. IEEE, 2007, pp. 2161-2166.

[9] A. J. Nicholson, Y. Chawathe, M. Y. Chen, B. D. Noble, and D. Wetherall, Improved access point selection, in Proceedings of the 4th international conference on Mobile systems, applications and services, 2006, pp. 233-245.

[10] Y. Chen, Q. Yang, J. Yin, and X. Chai, Power-efficient access-point selection for indoor location estimation, Knowledge and Data Engineering, IEEE Transactions on, vol. 18, pp. 877-888, 2006.

[11] Y. Fukuda, T. Abe, and Y. Oie, Decentralized access point selection architecture for wireless LANs, in Wireless Telecommunications Symposium, 2004, 2004, pp. 137-145.

[12] K. Kaemarungsi and P. Krishnamurthy, Analysis of WLAN's received signal strength indication for indoor location fingerprinting, Pervasive and mobile computing, vol. 8, pp. 292-316, 2012.

[13] H. Liu, H. Darabi, P. Banerjee, and J. Liu, Survey of wireless indoor positioning techniques and systems, Systems, Man, and Cybernetics, Part C: Applications and Reviews, IEEE Transactions on, vol. 37, pp. 1067-1080, 2007.

[14] A. W. S. Au, Rss-based wlan indoor positioning and tracking system using compressive sensing and its implementation on mobile devices, University of Toronto, 2010.

[15] Chen Feng, Research and implementation of RSS indoor positioning system based on compressed sensing, Beijing Jiao Tong Univeristy , 2011.