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A Study of Estimation of AP Position for Improvement of Indoor Positioning Performances

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Abstract

With the recent expansion of 3G and 4G networks and great popularity of smartphones, location-based applications in various smartphones have drawn great attention. At the same time, indoor positioning technology has emerged as well. There have been studies on the conventional indoor positioning techniques focusing on the triangulation technique which uses indoor WiFi signals. However, this triangulation technique is only available in the area where three or more mobile AP signals can be detected. This study examines the effect on positioning performances when new AP is added. It has also attempted to investigate the accuracy of AP position by localization algorithm and changes in the positioning results.

Keywords: *Position, WLAN, AP, RSSI*

1. Introduction

The WLAN-based positioning system uses the RSSI of Access Point(AP). The RSSI tends to decline over distance. [1] After setting a mathematical attenuation formula, the distance between a mobile user and wireless AP is estimated, and the estimation is used in positioning algorithm to locate the user. In conventional indoor positioning systems, it is assumed that there already exist a database which is called 'Radio Map,' the information of reference AP in which location is basically known for indoor positioning.[2] In a system in which positions are estimated by a user, it is generally supposed that an administrator server is delivered to the radio map by a user. If the position is estimated in the server, it is assumed that the radio map on the environment in which a user is currently positioned in the server is saved and used.[3] This kind of radio map makes it possible to classify the received signals at positioning. Then, it is used in positioning after estimating the distance up to AP position, which is recorded on the radio map.

In conventional positioning systems, however, there was no other methods except for the method to add AP positions to the radio map in the administrator even though the other AP except for the AP saved in the radio map is detected. According to previous studies, when a lot of APs were used in the same space, improved results were obtained. In actual system configuration, radio map was provided and managed by an administrator, not by a user. Therefore, it was difficult to use AP additionally until the revised radio map was provided by the administrator. [4]

This study investigates a method to localize unknown APs, not reference APs using WLAN-based indoor positioning algorithm and improve positioning accuracy by securing added AP position information.

2. WLAN-based Indoor Positioning

In general, RSSI is used for WLAN-based indoor positioning. Because the RSSI tends to decline over distance, an attenuation model is generally set and used in positioning. Since the RSSI is sensitive to the radio wave, however, there is difference with the actual attenuation model. As a result, a positioning error occurs. [5][6]

The RSSI is defined as the ratio of transmission and reception power. It reveals the strength of received signals in dBm.[7] The RSSI tends to decline exponently over distance. To apply the RSSI to the distance-based positioning method based on these attenuation characteristics, mathematical modeling is performed.[8][9] In fact, a variety of models which reflect the attenuation characteristics of the RSSI have been introduced. In this study, the attenuation model as shown in Equation (2-1) below has been used:

$$RSSI[dbm] = -(10n\log_{10}d - A) \quad (2\text{-}1)$$

n : Signal attenuation constant
d : Distance from signal source
A : RSSI measured at 1m (offset)

$$distance[m] = 10^{\frac{RSSI-A}{-10n}} \quad (2\text{-}2)$$

In the Equation 2-1, '*n*' is a signal attenuation constant which reflects the characteristics of RSSI which attenuates depending on circumstances while 'offset' refers to signal strength at 1m distance. The Equation 2-1 shows the relations of a log-attenuation model which has been set based on the collected RSSI. Then, distance is estimated according to the log-attenuation model and applied to the positioning.

3. AP localization Algorithm

Based on the positioning algorithm mentioned above, this study proposes algorithm which localizes the APs which are not found in the conventional AP database. First of all, both AP estimation scenario and algorithm are explained. Then, the impact of the addition of AP to the conventional database on positioning performance is examined through a test.

3.1. AP Localization Algorithm

The algorithm proposed in this study aims to localize a user and update and use radio map when the APs other than reference AP are searched using the first radio map provided by the administrator. The algorithm scenario is as follows:

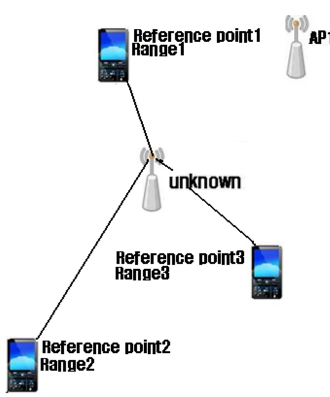

Figure 3-1. Conceptual Diagram of AP Localization in Reference Points

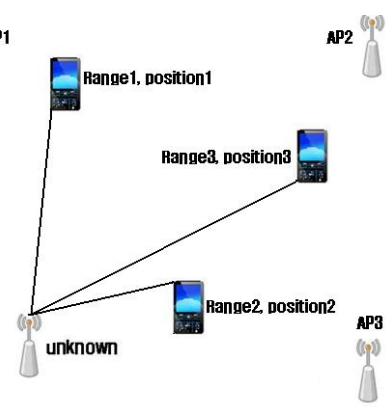

Figure 3-2. Conceptual Diagram of AP Estimation in Positioning

The first scenario is that reference points are known as shown in Figure 3-1. In this case, it is assumed that a user is aware of where reference points are located. First, a user measures and saves the RSSI at the reference points in order to figure out the position of unknown APs. If the measurement is done at more than three reference points, the position is estimated using the RSSI-based positioning algorithm proposed in Chapter 4 using the saved values. Then, the estimated AP positions are updated to the radio map and used in future positioning.

3.2. AP Localization Algorithm Test

The AP localization algorithm was tested in two cases as mentioned above. First of all, the radio map was recorded in the reference points after localizing APs. Based on the position, then, a positioning test was performed. After that, a test was conducted in assumption of the addition of APs.

3.2.1. Estimation at reference points-Estimation by AP

In the first test, the position of radio map APs was localized using the RSSI received in the reference points. Then, the localized positions were recorded in the radio map, and then positioning was performed.

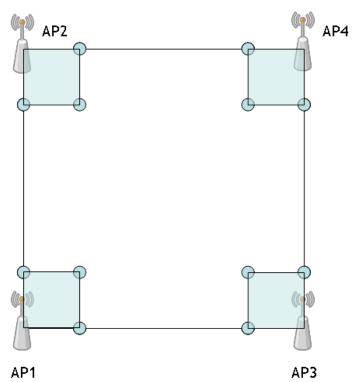

Figure 3-3. AP Localization Test in Reference Points (2m)

As shown in Figure 3-3, APs were localized by setting reference points and receiving the RSSI in each point. The reference points used in this test were 2m away from each AP.

Table 3-1. Estimated AP Positions (2m)

	X	Y
AP1(0,0)	-0.0294	-0.8035
AP2(0,10)	-0.1172	9.8635
AP3(10,0)	11.7045	0.9183
AP4(10,10)	11.4941	9.5911

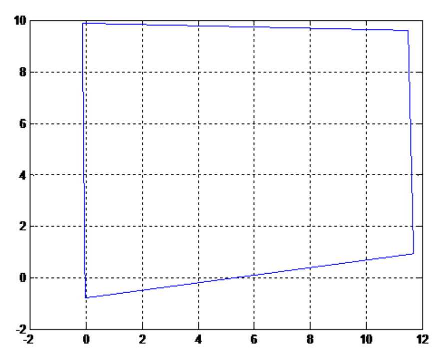

Figure 3-4. View of the Space Configured with the Estimated APs (2M)

Table 3-1 and Figure 3-4 show are the results of the estimation of AP positions. They show AP positions and the space created by them.

Table 3-2. Comparison between Use of Conventional AP Position and Use of Estimated Position (2m, error unit:m)

Position	Error (Before)	Error (After)	Variation	Position	Error (Before)	Error (After)	Variation
0,2	2.2408	2.6331	0.3923	6,0	4.0365	3.8571	-0.1794
0,4	2.5816	3.0482	0.4666	6,2	3.2865	3.7717	0.4852
0,6	2.3644	2.4119	0.0475	6,4	1.4674	1.4376	-0.0298
0,8	1.429	1.3747	-0.0543	6,6	2.2948	2.2255	-0.0693
2,0	1.18	0.5471	-0.6329	6,8	1.8073	2.3397	0.5324
2,2	1.2873	1.3317	0.0444	6,10	3.282	3.1927	-0.0893
2,4	0.4567	1.1328	0.6761	8,0	2.4852	2.0182	-0.467
2,6	1.2563	1.2742	0.0179	8,2	2.7658	2.1478	-0.618
2,8	0.3752	0.3677	-0.0075	8,4	2.8244	3.084	0.2596
2,10	1.39	1.1414	-0.2486	8,6	1.0877	0.3306	-0.7571
4,0	3.2833	2.548	-0.7353	8,8	0.99	0.5299	-0.4601
4,2	0.8361	0.5815	-0.2546	8,10	2.4472	2.1341	-0.3131
4,4	1.4475	2.5127	1.0652	10,2	0.8769	0.7566	-0.1203
4,6	0.9077	0.9397	0.032	10,4	3.0545	4.7776	1.7231
4,8	1.0472	0.9775	-0.0697	10,6	4.4965	4.133	-0.3635
4,10	3.254	3.0605	-0.1935	10,8	1.6696	1.349	-0.3206
				AVR	2.0065	1.9989	-0.0075

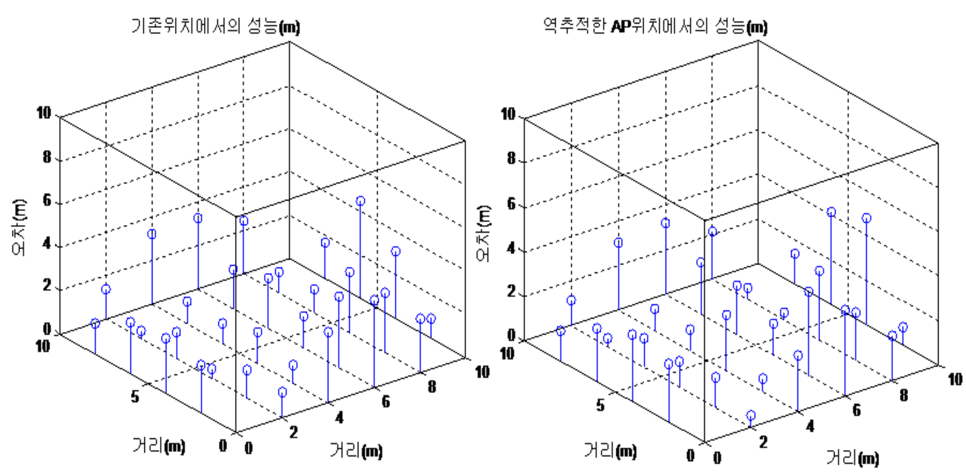

Figure 3-5. Use of Current AP Position (L) / Use of Estimated Position (R) (2m)

Table 3-2 and Figure 3-5 show the results of the use of the radio map in the conventional positions in positioning. Then, positioning results were estimated based on the estimation of AP positions in the radio map. Then, they were compared. The highlights in gray in Table 3-2 refer to the improved area compared to the conventional method. Performance was analyzed by performing positioning in each point 20 times. According to the analysis, when estimated with 2m distance, no big difference was observed compared to the case when the conventional radio map was used. Then, a test was performed by increasing the distance until the reference point to 6m.

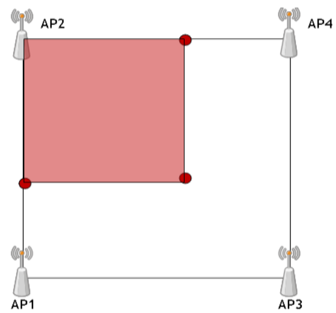

Figure 3-6. Localization in the Reference Points (6m)

Table 3-3. Estimated AP Positions(6m)

	X	Y
AP1(0,0)	-0.4370	0.5411
AP2(0,10)	-0.8670	9.3768
AP3(10,0)	8.7478	1.4197
AP4(10,10)	10.5308	11.4721

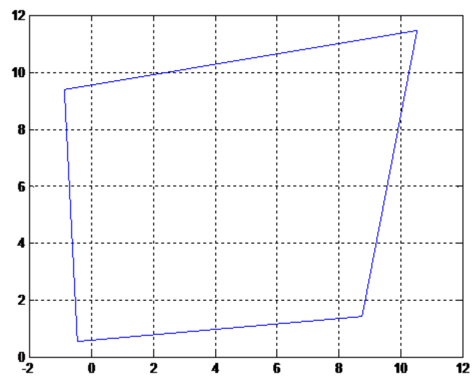

Figure 3-7. View of the Space Configured with the Estimated APs (6m)

Table 3-4. Comparison between Use of Conventional AP Position and Use of Estimated Position (6m, error unit: m)

Position	Error (Before)	Error (After)	Variation
0,2	2.2408	1.8536	-0.3872
0,4	2.5816	2.3619	-0.2197
0,6	2.3644	1.7341	-0.6303
0,8	1.429	1.1093	-0.3197
2,0	1.18	1.8109	0.6309
2,2	1.2873	1.434	0.1467
2,4	0.4567	0.3771	-0.0796
2,6	1.2563	1.3756	0.1193
2,8	0.3752	0.8412	0.466
2,10	1.39	1.3425	-0.0475
4,0	3.2833	2.2205	-1.0628
4,2	0.8361	2.1767	1.3406
4,4	1.4475	0.875	-0.5725
4,6	0.9077	1.4587	0.551
4,8	1.0472	0.998	-0.0492
4,10	3.254	1.4713	-1.7827

Position	Error (Before)	Error (After)	Variation
6,0	4.0365	5.6127	1.5762
6,2	3.2865	5.3447	2.0582
6,4	1.4674	2.1057	0.6383
6,6	2.2948	2.504	0.2092
6,8	1.8073	1.7027	-0.1046
6,10	3.282	2.9231	-0.3589
8,0	2.4852	4.3212	1.836
8,2	2.7658	4.6891	1.9233
8,4	2.8244	4.315	1.4906
8,6	1.0877	2.1286	1.0409
8,8	0.99	1.3594	0.3694
8,10	2.4472	0.7661	-1.6811
10,2	0.8769	2.2289	1.352
10,4	3.0545	2.4612	-0.5933
10,6	4.4965	4.5764	0.0799
10,8	1.6696	2.6502	0.9806
평균오차	2.0065	2.2285	0.27875

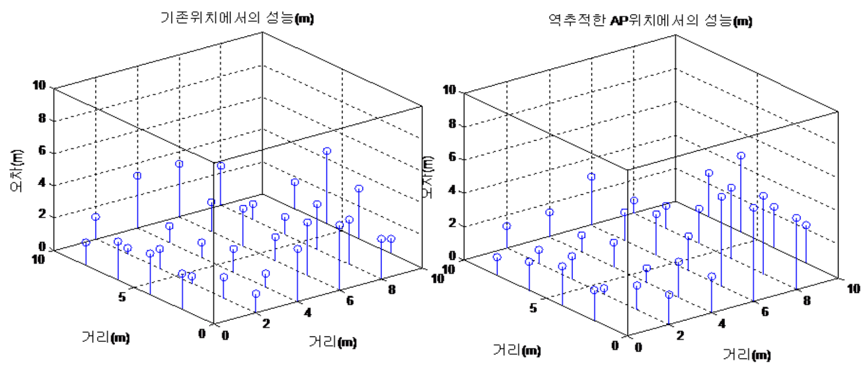

Figure 3-8. Use of Current AP Position (L) / Use of Estimated Position (R) (6m)

Table 3-3 and Figure 5-7 show AP positions and the spaces based on the results of AP localization. According to Table 3-4 and Figure 3-8, it can be estimated that position accuracy declined by about 27cm when compared to the case that the conventional radio map was used when estimated with 6m distance. According to an analysis on the AP localization test with 2m and 6m distance, the result was similar to that of the conventional radio map within 6m distance when AP localization results were used in radio map configuration.

3.2.2. Addition of AP Positions during Positioning

In the 2nd test, the addition of the position to the radio map was examined when applicable APs were added during positioning. The test was conducted in assumption that the position of AP2 was added during positioning as shown in Figure 3-9.

The test scenario is that the information of the rest AP was used when the position of AP2 was not available in the radio map in assumption that the AP2 position was unknown. Then, positioning was performed after adding the results of AP2 localization to the radio map. In an actual test, positioning was performed using the radio map in which AP1, AP3 and AP4 position information is saved around the AP2 (6m) as shown in Figure 3-9. Then, the positioning results and the RSSI at AP2 were saved. After that, the position of AP2 was estimated. The results of the positioning were confirmed while the position of AP2 was not found in the radio map. Then, they were compared when the position of AP2 was added to the radio map.

Table 3-5. Case without AP2 Position and AP2-estimated Position

Position	Error (Before)	Error (After)	Variation
0,2	4.0558	2.3558	-1.7
0,4	2.797	2.5816	-0.2154
0,6	11.3906	2.1956	-9.195
0,8	5.4827	1.265	-4.2177
2,0	1.4272	1.18	-0.2472
2,2	1.2873	1.2873	0
2,4	1.0099	0.4567	-0.5532
2,6	2.1729	1.181	-0.9919

Position	Error (Before)	Error (After)	Variation
6,0	4.0365	4.0365	0
6,2	2.9879	3.6214	0.6335
6,4	3.0946	1.4376	-1.657
6,6	0.8739	2.3865	1.5126
6,8	2.5723	1.8073	-0.765
6,10	0.8117	3.1927	2.381
8,0	2.4852	2.4852	0
8,2	2.7658	2.7658	0

2,8	3.1481	0.3677	-2.7804
2,10	13.9866	1.4065	-12.5801
4,0	3.2833	3.2833	0
4,2	0.8361	0.8361	0
4,4	1.4475	1.4475	0
4,6	2.2948	0.9397	-1.3551
4,8	3.3551	0.9775	-2.3776
4,10	11.4266	3.254	-8.1726
8,4	1.6897	2.8244	1.1347
8,6	1.0877	1.0877	0
8,8	0.9465	0.99	0.0435
8,10	3.0719	2.4472	-0.6247
10,2	1.4795	0.8769	-0.6026
10,4	3.795	3.0545	-0.7405
10,6	4.4965	4.4965	0
10,8	1.6696	1.6696	0
AVR	3.3520	2.0060	-1.3460

The test results are shown in Table 3-5 and Figure 3-9. In average, performance improved by about 1.3m. In particular, error in the AP2 when the position of AP2 was unavailable greatly improved.

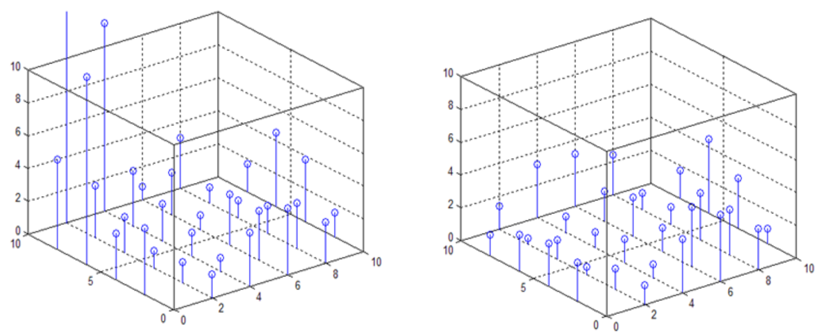

Figure 3-9. Case without AP2 Position (L)/Use of AP2-estimated Position (R) (6m)

4. Realtime Positioning System Configuration

Based on the test above, an indoor positioning system in which realtime positioning and radio map management are possible can be configured as follows:

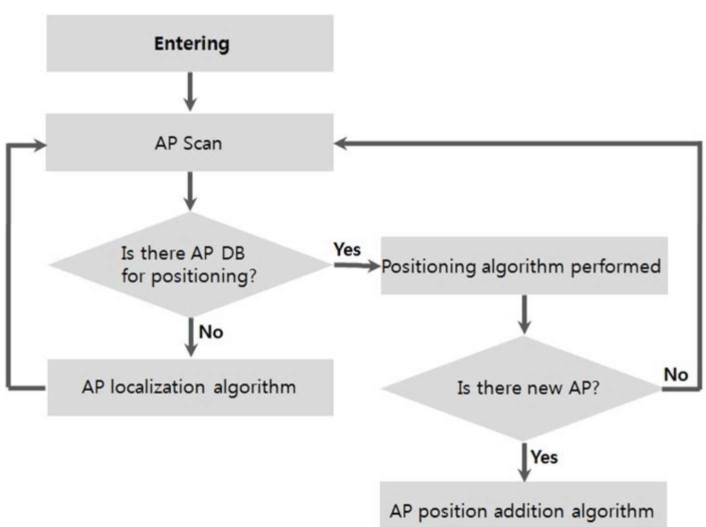

Figure 4-1. Realtime Positioning Algorithm Flowchart

First, once a user enters, the radio map in which map information and reference AP position on the indoor space are saved is received. Then, it is assumed that there exist a sufficient number of APs enough to perform positioning. Before starting positioning, whether or not the number of reference APs saved in the radio map is sufficient enough to perform positioning. If the received information on radio map is sufficient, positioning is performed. If it isn't, it is moved back to the predefined reference point, and AP positions are estimated. Then, they are additionally added to the radio map. Once the information on radio map is sufficient, positioning is performed using the received RSSI.

If new AP is received while positioning is being performed, the AP addition algorithm is used among the AP localization algorithms proposed above.

5. Conclusion

In this study, an algorithm on the method to localize unknown APs, not reference APs using the WLAN-based indoor positioning algorithm and improve positioning accuracy by securing the AP position information by using them in positioning again. Then, its performance has been examined through a test. Based on the test, this study has proposed an algorithm which is applicable to realtime positioning and confirmed its possibility. However, it is necessary to keep studying a way to increase signal reliability in WLAN-based RSSI positioning.

In addition, this study has failed to consider the frequent changes of indoor environment. Actually, air can cause free space path loss, and walls and people can attenuate the RSSI. Therefore, a further study needs to conducted on the improvement of reliability through establishment of an attenuation model which considers these diverse indoor environment and the analysis and management of RSSI data.

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