An Enhanced IEEE 802.11 RSSI Measurement Compensation Method Using Kalman Filter

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***Abstract*— With the development of indoor positioning technology, the demand for accurate positioning is getting higher. Moreover, location determination technologies especially for indoor environments are getting a lot of attention. For more accurate positioning, the more accurate distance information should be determined. Existing distance determination methods using Received Signal Strength Indicator (RSSI) measurements are mostly processed by simple averaging. That has some limitations to remove variable noise sources. In this paper, we adopt Kalman filter to get more accurate distance information from RSSI measurements. Our proposed method improves distance measurement accuracy about 68.3% and 41.8%, respectively.**

Keywords- RSSI; Kalman filter.

I. INTRODUCTION

In the era of mobile internet services, Location Based Service (LBS) is one of key-role playing mobile services. Therefore, the position information of human or objects are getting more attention. At present, people can have position information from GNSS(Global Navigation Satellite System), A-GPS(Assisted GPS), TC-OFDM technology. Ultrasonic technology, Radio Frequency Identification technology (RFID), geomagnetic positioning technology, etc. [1][2].

In outdoor environments, satellite navigation system such as GPS is the most reliable and accurate positioning system. However, almost 80 % of our ordinary daily life is executed in indoor environments. Therefore, we need an indoor positioning method showing stable and accurate performance just like outdoor GPS.

Now, there are various indoor positioning methods using infrared, ultrasonic, Bluetooth, RFID, UWB and WLAN, etc. We can find out the common development trends of indoor positioning methods in 4 aspects.

Aspect 1: Positioning accuracy improvement (nearing to that of GPS)

Aspect 2: Positioning efficiency improvement

Aspect 3:.Cost Reduction of indoor positioning signal coverage.

Aspect 4: Fusion with outdoor positioning technology (for seamless positioning)

Hence, we focus on indoor positioning method based on IEEE802.11 WLAN, which is the most widely spread wireless communication network.

In Section II, we propose an RSSI measurement compensation method using Kalman filters. Simulation results and concluding remarks are given in Sections III and IV, respectively.

II. PROPOSED METHOD

In this paper, We propose a IEEE802.11 RSSI measurement compensating method for more precise indoor positioning by adopting Kalman filter.

A. RSSI Attenuation Model

The Received Signal Strength Indicator (RSSI) defines a measurement of RF energy and its unit is dBm. The RSSI is decreased exponentially as the distance from an AP (Access Point) is increased. Because of these characteristics, in this paper we used an RSSI attenuation model and it is given as [3][4]

$$\mathrm{RSSI[dBm]} = -10\mathrm{n}\log_{10}\frac{d}{d_0} + A \qquad (1)$$

$$\mathrm{d[m]} = 10^{\frac{\mathrm{RSSI}-\mathrm{A}}{-10\mathrm{n}}} \qquad (2)$$

In (1), n is the attenuation factor, parameter A is the offset which is the measured RSSI value at a reference point (usually 1m) apart from the AP, and d is the distance from AP. These parameters reflect the indoor propagation environments. RSSI is a sensitive measurement which can be significantly affected by the environment. Fig. 1 shows that RSSI measurements are attenuated by log scale as distances are increased.

In common situations, many factors can affect the RSSI value such as furniture, walls and pedestrians, etc. These factors can produce scattering signals and a multipath effect. Thus, it can result in positioning error. In order to reduce positioning error, proper parameter determination is necessary.

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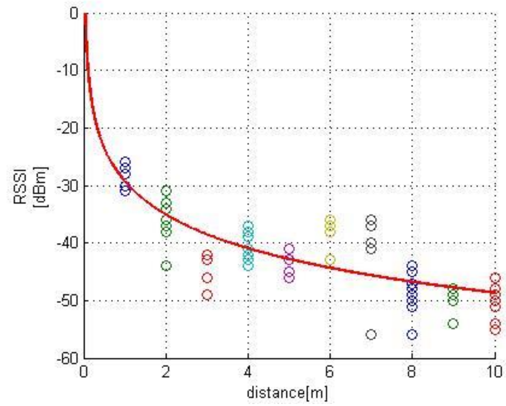

Figure 1. RSSI Attenuation according to the Elapsed Distance

B. Kalman Filter

Linear system state equation and measurement equation is as follows:

$$\mathrm{x}(\mathrm{k}+1)=\mathrm{F}(\mathrm{k})\mathrm{x}(\mathrm{k})+\mathrm{G}(\mathrm{k})u(k)+v(k) \quad (3)$$

$$\mathrm{z}(\mathrm{k}+1)=\mathrm{H}(\mathrm{k})x(k+1)+\omega(k+1) \quad (4)$$

x(k) represents a state vector at time k. F(k) and G(k) are state matrix and input matrix, respectively. $v(k)$ means process noise at time k. z(k) represents an output vector at time k. H(k) is measurement matrix. $\omega(k+1)$ means measurement noise at time k+1.

Kalman filtering procedures are made up of two processes such as prediction and state update [5]. Firstly, we predict state, measurement and covariance. After that, we calculate Kalman gain using predicted information at first step. Finally, we update state estimate and state covariance using Kalman gain.

$$\hat{x}(k+1|k)=\mathrm{F}(\mathrm{k})\hat{x}(\mathrm{k}|\mathrm{k})+\mathrm{G}(\mathrm{k})u(k) \quad (5)$$

$$\hat{z}(k+1|k)=H(\mathrm{k})\hat{x}(\mathrm{k}+1|\mathrm{k}) \quad (6)$$

$$\mathrm{P}(\mathrm{k}+1|\mathrm{k})=\mathrm{F}(\mathrm{k})\mathrm{P}(\mathrm{k}|\mathrm{k})\mathrm{F}(\mathrm{k})'+\mathrm{Q}(\mathrm{k}) \quad (7)$$

$$Q(k)=\mathrm{E}[v(k)v(k)'] \quad (8)$$

$$\mathrm{H}(\mathrm{k}+1)\mathrm{P}(\mathrm{k}+1|\mathrm{k})H(k+1)' \quad (9)$$

$$R(k)=\mathrm{E}[w(k)w(k)'] \quad (10)$$

$$v(k+1)=z(k+1)-\hat{z}(k+1|k) \quad (11)$$

$$\mathrm{W}(\mathrm{k}+1)=\mathrm{P}(\mathrm{k}+1|\mathrm{k})\mathrm{H}(\mathrm{k}+1)'\mathrm{S}(\mathrm{K}+1)^{-1} \quad (12)$$

$$\hat{x}(k+1|k+1)=\hat{x}(k+1|k)+W(k+1)v(k+1) \quad (13)$$

$$\mathrm{P}(\mathrm{k}+1|\mathrm{k}+1)=\mathrm{P}(\mathrm{k}+1|\mathrm{k})-W(k+1)S(k+1)W(k+1)' \quad (14)$$

$\hat{x}(k+1|k)$ represents state estimate at time k+1 given measurements until time k. $\hat{x}(k+1|k+1)$ represents state estimate at time k+1 given measurements until time k+1. $\hat{z}(k+1|k)$ represents measurement estimate at time k+1 given measurements until time k. $\mathrm{P}(\mathrm{k}+1|\mathrm{k})$ means error covariance matrix at time k given measurements until time k. Q(k) and R(k) are the covariance matrix of process noise and measurement noise, respectively. W(k) is the optimal Kalman gain.

We define state vector x(k) with RSSI(k) and d(k), where RSSI(k) is the RSSI measurement at time k and d(k) is distance at time k. We made F(k), G(k) from the RSSI attenuation model given by Eq. (1) and Eq. (2). H(k) is defined as in (19).

$$\mathrm{x}(\mathrm{k})=\begin{bmatrix} RSSI(k) \\ d(k) \end{bmatrix} \quad (16)$$

$$\mathrm{F}(\mathrm{k})=\begin{bmatrix} 1 & \frac{10nlog_{10}d(k)}{d(k)} \\ 0 & 1 \end{bmatrix} \quad (17)$$

$$\mathrm{G}(\mathrm{k})=\begin{bmatrix} \frac{-10nlog_{10}(d(k)+u(k))}{u(k)} \\ 1 \end{bmatrix} \quad (18)$$

$$\mathrm{H}(\mathrm{k})=\begin{bmatrix} 1 & 0 \end{bmatrix} \quad (19)$$

III. SIMULATION RESULTS

We assume the Kyungpook National University IT-1 building's first floor as simulation environments. This building has attenuation factor *n* which is 2.7. The process noise $v(k)$ is modeled uniform distribution. It has zero mean and 0.01 variance. Measurement noise $\omega(k)$ is modeled as Gaussian. It has zero mean and 2.12 variance. In this paper, we consider two simulation situations: one is regular step situation and the other is random step. Fig 2 is sectional view of Kyungpook National University IT-1 building

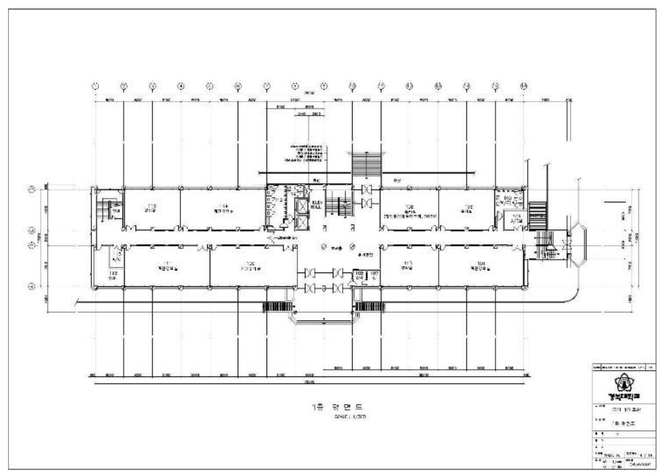

Figure 2. Kyungpook National University IT-1 Building (First Floor)

In this simulation, we symbolize Measurement as existing distance determination method, which decides RSSI measurement at a point by averaging multi epoch RSSI measurements at the point. Also, we symbolize Estimation as the proposed distance calculation method.

Existing method (Measurement) determines the distance of a point by averaged multi epoch RSSI measurements around the point. On the other hand, Proposed method (Estimation) determines the distance of a point by Kalman filtered each epoch RSSI measurement around the point.

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A. Regular Step Situation

Regular step situation means a movement with 0.1m distance in every second from 1m to 10m. Fig. 3 shows the regular step situation which goes away from AP, regularly.

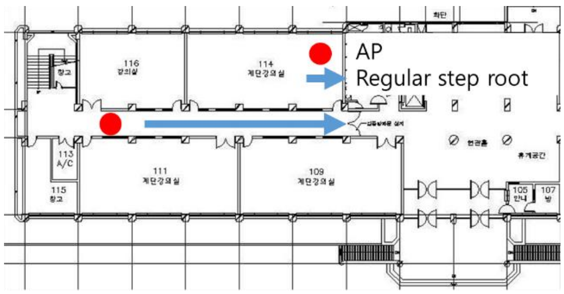

Figure 3. Regular Step Situation

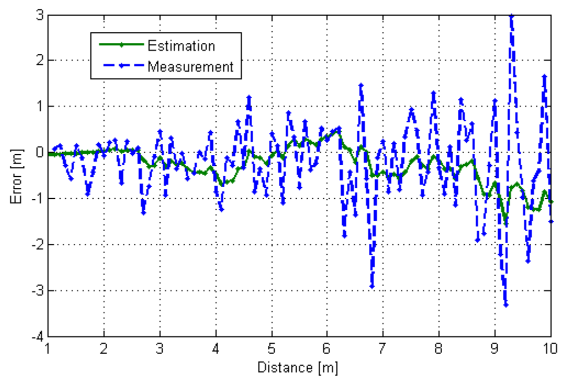

Figure 4. Distance Error of Measurem ent and Estimation (Regular step)

Fig. 4 shows distance errors of Measurement and Estimation. The green line (Estimation) is closer to the zero line more than the blue line. For random step situation, the distance errors and variances of Measurement and Estimation are given in Table I, respectively.

TABLE I. DISTANCE ERROR OF MEASUREM ENT AND ESTIMATION(REGULAR STEP)

	Error [m]	Variance
Measurement	0.82	0.69
Estimation	0.26	0.08

The distance error of the proposed method (Estimation) is less than that of existing one (Measurement) by 0.56m. It means that for regular step situation, the proposed method (Estimation) will produce 68.3% less distance error, compared with existing method (Measurement).

B. Random Step Situation

Random step situation means a movement with random distance in every second. This random distance is modelled as Gaussian with 0 mean and 1.2 variance. Fig. 5 shows the random step situation which describes wandering around AP within 10m.

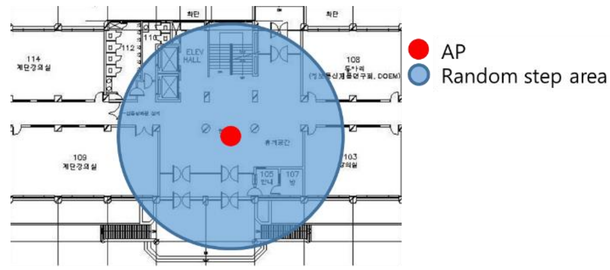

Figure 5. Random Step Situation

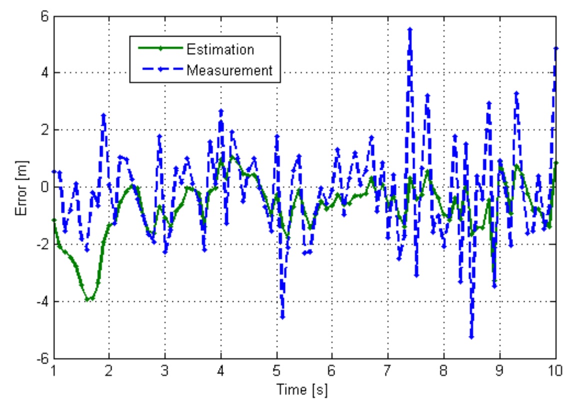

Figure 6. Distance Errors of Measurement and Estimation(

Fig. 6 shows distance errors of Measurement and Estimation. The blue line is distance error from Measurement. The green line is distance error from Estimation. The green line is closer to the zero line than the blue line. For random step situation, the distance errors and variances of Measurement and Estimation are given in Table II, respectively.

TABLE II. DISTANCE ERROR OF MEASUREM ENT AND ESTIMATION(RANDOM STEP)

	Error [m]	Variance
Measurement	1.84	3.56
Estimation	1.07	0.92

The distance error of the proposed method (Estimation) is less than that of existing one (Measurement) by 0.77m. It also means that for random step situation, the proposed method (Estimation) will produce 41.8% less distance error, compared with existing method (Measurement).

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IV. CONCLUSIONS

In this paper, we proposed an RSSI measurement compensation method using Kalman filter to reduce the calculated distance errors, which results in a more accurate indoor positioning. By estimating the noises in RSSI measurements using Kalman filter, we can compensate the estimated noises from RSSI measurements and calculate more precise distance information, which results in a more precise positioning.

Simulation results for the two representative situations, regular step situation and random step one, show that the distance error of the proposed method (Estimation) can be improved over that of the existing method (Measurement) by 68.3% and 41.8%, respectively.

For future works, we are trying to classify indoor environments in more detail. Attenuation factor (*n*) and offset (*A*) of RSSI attenuation log model are dominantly dependent on applied environments. The RSSI attenuation log model, which is adapted to real indoor environment, will provide more accurate distance information.

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