Adaptive Path-loss Model-based Indoor Localization

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Abstract—In this paper, we present new received signal strength (RSS)-based indoor localization system. In indoor environment, it is not desirable to use a theoretical signal propagation path-loss model. The signal propagation is severely affected by surrounded object, especially metallic object. In order to cope with this problem, we introduce a new path-loss exponent estimation (PLE) node. This node generates a path-loss model appropriate for a given space. We then determine a mobile node’s location based on the new path-loss model. Since PLE node operates in real time manner, it can robustly adapt the path-loss model for the circumstance. We evaluate our adaptive path-loss model-based localization system through actual experimental tests.

I. INTRODUCTION

Location is one of the most important factors in mobile robot applications and home/factory automation. For example, in a trajectory tracking problem, it is basically required to locate objects and pedestrians for intelligent service [1].

Lots of low-cost localization systems have been reported for indoor environment. Some of the systems are especially based on RF signal strength called received signal strength (RSS). RSS measurement is transformed to a distance from a known reference point to a target object based on signal propagation path-loss model [2]. RSS is also used as a unique feature for a location [3, 4, 5], which is called fingerprinting. These RSS-based systems are effective, but they have to inspect a given space in advance. This inspecting process is time consuming and cannot represent time-dependent variation of signal strength. In this paper, we present a new RSS-based indoor localization system. In order to cope with the inspecting-problem, we introduce a path-loss estimation (PLE) node. The PLE node adapts a signal path-loss model for the circumstance in terms of path-loss exponent $\alpha$ in real time manner. The target object then determines its location based on the adapted path-loss model.

II. LOCALIZATION ALGORITHM

The wireless sensor network (WSN) consists of beacon nodes and one mobile node located at known locations and unknown location, respectively. If we know a distance $r_i$ between the $i$-th beacon node and mobile node, we can determine the mobile node’s location $(x, y)$ by solving:

$$r_i^2 = (x - x_i)^2 + (y - y_i)^2, \quad i = 1, \ldots, 3 \quad (1)$$

where we obtain $r_i$ from RSS [1]. The well-known radio signal propagation path-loss model transforms the RSS measurement into a distance as follows [2,3,6,7]:

$$P_i = 10\alpha \log_{10} \frac{r_i}{r_0} + P_0, \quad i = 1, 2, 3 \quad (2)$$

where $P_i$ is a RSS measurement of the signal from the $i$-th beacon node, and $\alpha$ is a path-loss exponent. $r_0$ is a unit distance and $P_0$ is a RSS measured on a distance of $r_0$. Note that $P_0$ can be given by hardware manufacturer or obtained from prior tests.

Using the PLE node, we can adapt the unknown $\alpha$ of path-loss model for a given space. The PLE node is placed at a known location, so that the distance $r_{PLE,i}$ between the $i$-th beacon node and PLE node is easily calculated. $P_{PLE,i}$ of the PLE node is a measured RSS of the signal from the $i$-th beacon node. Thus, the circumstance–associated path-loss exponent $\alpha_{PLE,i}$ is obtained by substituting $r_{PLE,i}$ and $P_{PLE,i}$ for $r_i$ and $P_i$ of (2). We suggest two ways of combining several $\alpha_{PLE,i}$ to determine the $\alpha$ of the space. First approach is averaging every $\alpha_{PLE,i}$, and second approach is letting $\alpha_m$ be the $\alpha$ when $\alpha_m$ is an average of $\alpha_{m,i}$ of the $m$-th PLE node. In the second approach, it is required to select appropriate PLE node for the space. We choose the PLE node whose RSS measurements are the closest to RSS measurements of the mobile node. We estimate $r_i$, and then determine the mobile node’s location by triangulating $r_i$.  

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III. EXPERIMENT

A. Equipments

We made new nodes for experiment. The nodes communicate based on IEEE 802.15.4 Low-Rate (LR) Wireless Personal Area Network (WPAN) standard [8]. We have two types of node; beacon node and mobile node.

B. Localization Performance

We evaluated a performance of our localization system. The experiment was conducted at our office. The office space is depicted in fig. 2, wherein we installed a wireless sensor network (WSN).

![Fig. 2. Office environment and WSN installation.](image)

First, we tested our system with one PLE node 6F4A. We took smallest three RSS measurements into account when we determine the mobile node’s location. Fig. 3 and table 1 show the test results. Fig. 3 shows the estimation errors vs. indoor points. Our system provides effective locations with an average error of 2.5 m. Next, we tested using three PLE nodes. Fig. 4 and table 2 show the results. We used the second combining approach.

![Fig. 3. Localization result with one PLE node](image)

![Fig. 4. Localization result with three PLE nodes and second method](image)

### TABLE I

<table>
<thead>
<tr>
<th>Error (m)</th>
<th>Average (m)</th>
<th>Min (m)</th>
<th>Max (m)</th>
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<tr>
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<td>2.50</td>
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### TABLE II

<table>
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IV. CONCLUSION

In this paper, we described the adaptive path-loss model-based indoor localization system. This system considers environmental characteristic in terms of path-loss exponent \( \alpha \), so that it effectively determines a location of a mobile node. Using one PLE node, localization accuracy reaches 2.5 m. In addition, since \( \alpha \) is estimated in real time, our system is robust against variation of the circumstance.

REFERENCES


