PRECISE POSITIONING METHOD FOR LOGISTIC TRACKING SYSTEMS USING PHS BASED ON MAHALANOBIS DISTANCE

Naoaki YOKOI, Yasuhiro KAWAHARA and Hiroshi HOSAKA*

* Department of Human and Engineered Environmental Studies, Graduate School of Frontier Sciences, The University of Tokyo
5-1-5 Kashiwanoha, Kashiwa-shi, Chiba 277-8563, JAPAN
E-mail: yokoi@ems.k.u-tokyo.ac.jp
E-mail: yasu@ems.k.u-tokyo.ac.jp

ABSTRACT

Focusing on the PHS positioning service used in physical distribution of logistics, a positioning error offset method for improving positioning accuracy is invented. The PHS system has a defect that the measurement errors are large ranging from several tens of meters to several hundred meters caused by the fluctuation of radio waves by buildings around the terminal. In this research, an error offset method is developed which learns patterns of positioning results (latitude and longitude) containing errors and the highest signal strength at major logistic points in advance, and matches them with the new data measured at actual distribution processes according to Mahalanobis distance. Then the matching resolution is reduced to 1/40 of the conventional error offset method.

1. INTRODUCTION

Recently, the PHS modules have been drastically miniaturized producing such as W-SIM device with the development of microsystem technologies. In the sensor networks, the positioning technology is one of the most important applications. In particular, there is a growing need for the positioning system using PHS in the logistics field, since the initial cost is almost zero, the system can track transport equipment both inside and outside buildings, and the terminals need little electricity to work [1]. However, the PHS system has a defect that the measurement error is large ranging from several tens of meters to several hundred meters. In order to overcome this problem, an error offset method for improving positioning accuracy is developed.

2. PHS POSITIONING METHOD

2.1 RSSI positioning method

Position calculating method in this research using PHS is called RSSI (Received Signal Strength Indicator) positioning method. This method is a technique to estimate the terminal location based on the plural CS (Cell Station) location and RSSI data of radio waves from each CS. These data can be measured by a PHS terminal. In the actual measurement environment, the measured RSSI data contains error caused by the attenuation of radio waves by buildings around the terminal. However, the CS’s that the terminal catches often concentrate around the terminal [2]. Consequently, in this research, the estimated location of terminal (x, y) was calculated by centroid positioning method.

\[
(x, y) = \frac{\sum_{i=1}^{N} m_i (x_i, y_i)}{\sum_{i=1}^{N} m_i}
\]

(3)

Here, \( m_i \) shows the RSSI of radio wave, \( (x_i, y_i) \) shows the position coordinates of CSs, and \( N \) shows the number of received CS’s in descending order of RSSI.

1.2 Position matching

PHS positioning system is primarily used in location information management of the transport equipments and the valuables. Practically, the system is often used in combination with position-matching method which registers the locations of the warehouses and offices in advance where the equipment might move, and then ascribes the terminal location to a registered position when the calculated position is within 1 km from the position. As for this method, when the distance among registered positions becomes 2 km or less, it is not possible to use. Therefore, in this research, an error offset method is developed which learns patterns of positioning results (latitude and longitude) containing errors and the highest signal strength at major logistic points in advance, and matches them with the new data measured at actual distribution processes according to Mahalanobis distance.

3. ERROR OFFSET METHOD

3.1 Measurement condition

The RSSI data of each CS were measured with a PHS terminal AH-N401C (NEC). By one measurement, RSSI and CS-ID of each CS around the PHS less than 20 are acquired. The location of the CS can be specified by acquired CS-ID. Figure 1 shows the RSSI measuring points donated by the cross marks of A–F that exist at intervals of about 50 m on a route in Chiba Prefecture, Japan. Among the measured RSSI data, 200 data were used for the training data, and 100 data were used for the
evaluation between the training data and test data. Mahalanobis distance is expressed as Euclidean distance divided by the standard deviation of data. In the case of three dimensions, Mahalanobis distance is defined in the following expressions:

\[
D_{ij} = \left[ (x_i - x_j)^2 + (y_i - y_j)^2 + (z_i - z_j)^2 \right]^{1/2}
\]

where \( (x, y, z) \) shows the positioning result and highest RSSI of the test data, \( (x_1, y_1, z_1) \) shows the average value of training data on each point, \( (x_2, y_2, z_2) \) shows variance of each parameter of training data and \( (x_3, y_3, z_3) \) shows the covariance between each parameter. When the test data is obtained, the point where the data might be measured is distinguished as a point where the training data that the Mahalanobis distance is minimized was measured. Table 1 shows the position discriminant results of the test data measured in each measurement point in Fig. 1 using training data and Mahalanobis distance. Using this location evaluation method, it is possible to identify the terminal location with accuracy of around 95% at intervals of 50 m. This result indicates that the space resolution was improved to 1/40 compared with conventional position-matching method.

Table 1 Distinction results using Mahalanobis distance

<table>
<thead>
<tr>
<th>Discriminant result</th>
<th>Point-A</th>
<th>Point-B</th>
<th>Point-C</th>
<th>Point-D</th>
<th>Point-E</th>
<th>Point-F</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>100</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Point-B</td>
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<td>90.0</td>
<td>0</td>
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<td>Point-C</td>
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<td>95.7</td>
<td>0</td>
<td>0</td>
<td>1.4</td>
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<td>Point-D</td>
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<td>0</td>
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<tr>
<td>Point-E</td>
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<td>0</td>
<td>84.5</td>
<td>5.7</td>
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<tr>
<td>Point-F</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
</tbody>
</table>

5. CONCLUSION

In this research, focusing on the PHS positioning service used in logistics, an error offset method for improving positioning accuracy was invented and evaluated. Using this location evaluation method, it is possible to identify the terminal location with accuracy of around 99% at intervals of 50 m. Then the space resolution was improved to 1/40 compared with conventional position-matching method.

REFERENCES