POSITION ESTIMATION SYSTEM MAKING USE OF SIGNAL STRENGTH OF WIRELESS LAN IN A SHIPYARD

H Kimura, Kyushu University, Japan
N Iwauchi, Tsuneishi Shipbuilding Co., Ltd., Japan
Y Yoshida, Kawasaki Heavy Industries, Ltd., Japan

SUMMARY

In shipyards, it is required to obtain the position of people and goods in order to manage people, objects, improve work placement, and secure workers' safety. Although the most popular location estimation is GPS, it cannot be used for position detection in a building with a roof. Meanwhile, the infrastructure of the wireless LAN has been in place in recent factories of shipyards, and if these can be used for position detection, the installation cost of dedicated facilities for position detection can be reduced. In this research, we investigate a location estimation method using radio field intensity of unspecified number of wireless LANs without specifying the access point installation site of wireless LAN, and verify the position estimation accuracy inside the building of the shipyard.

1. INTRODUCTION

In shipyards, it is required to obtain the position of people and goods in order to manage people, objects, improve work placement, and secure workers' safety. Although the most popular location estimation is GPS, it cannot be used for position detection in a building with a roof. Instead, there exists devices and services that use radio waves or ultrasonic waves to specify the location in a building [1]. They are used by installing special devices such as dedicated beacons, antennas, and wireless devices. However, using such special equipment and services in a shipyard is unfortunately not cost effective. Meanwhile, the infrastructure of the wireless LAN has been in place in recent factories of shipyards, and if these can be used for position detection, the installation cost of dedicated facilities for position detection can be reduced. In this research, we investigate a location estimation method using radio field intensity of unspecified number of wireless LANs without specifying the access point installation site of wireless LAN, and verify the position estimation accuracy inside the building of the shipyard.

2. LOCATION ESTIMATION METHODS MAKING USE OF WIRELESS-LAN

Existing wireless-LAN location detection methods are roughly divided into the following three types:

(a) Triangulation: It is a method to perform position estimation using relative distance from the base station whose position is known (Fig.1). The distance is calculated using the radio intensity of the base station (Wi-Fi router) observed at the terminal to be estimated. However, radio waves are often not attenuated according to the distance characteristics due to the effects of reflected waves and scattered waves from obstacles and walls, so it is difficult to apply them indoors with many walls and fixtures. This method cannot be used because we do not use the location information of the wireless base station in this research.

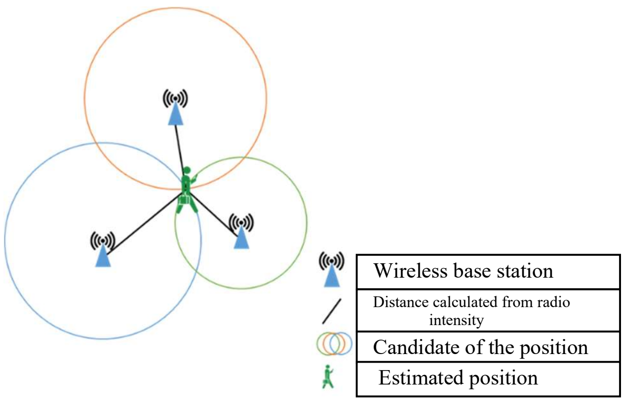


Fig.1 Triangulation

(b) Proximity: A method to identify which wireless LAN base is close to the estimation target by the reception strength of the estimation target. The location information of the wireless LAN base station and the range covered by each base station must be grasped in advance, and the estimation result is relatively low because it is the entire range covered by the wireless base station. It cannot be used in this research because it requires location information of the base station as in (a).

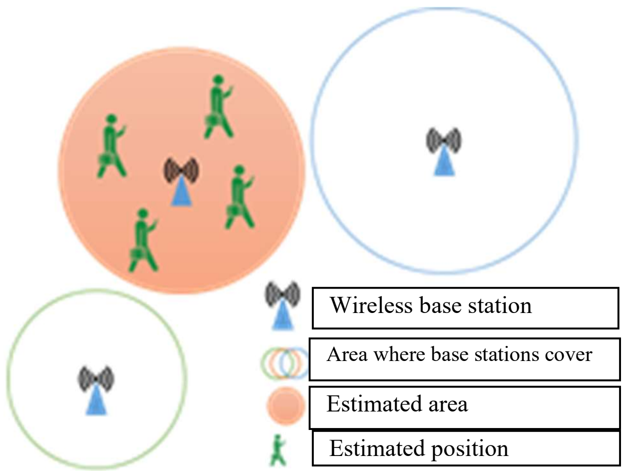
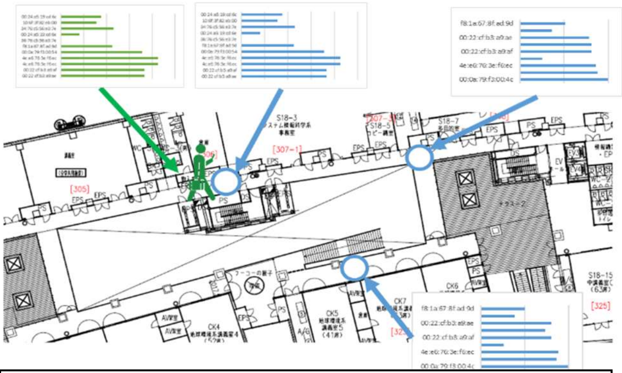


Fig.2 Proximity

(c) Scene Analysis: Scene analysis is a method of observing scenes at a plurality of positions in the target area, constructing each database and its observed position information into a database or machine learning in advance, and using it for position estimation. At the time of estimation, the scene observed from the terminal to be estimated is compared with the database prepared in advance, and the position is estimated based on which position in the database is similar to the observed scene. In this method, the influence of reflected waves and scattered waves is taken into consideration, and by narrowing the distance between points to be observed in advance, it is possible to improve the position estimation accuracy instead of increasing the amount of data. This method is adopted in this research.



Blue: Observed BSSID intensity and positions in advance

Green: BSSID intensity of a query and its estimated position

Fig.3 Scene Analysis

As a previous study of position estimation by Scene Analysis, Fujita et al. [3] assumed wireless LAN received radio wave intensity as a normal distribution, and mixed radio wave received intensity model with Gaussian mixture model using linear combination of normal distribution called normal mixture. And the system estimates the position by maximum likelihood estimation after making it. However, in this method, the coupling weights are manually adjusted during mixed normal distribution model generation, and the effectiveness is questioned, such as creating a model using far more basis functions than observed data points for model generation. In this study, we propose a new method of performing position estimation using a method similar to image filtering, which performs function approximation with minimum necessary resources for previously observed data points.

3. A NEW LOCATION ESTIMATION ALGORITHM IN SCENE ANALYSIS

3.1 FLOW OF THE POSITION ESTIMATION

An overview of the position detection procedure of this method is shown in Fig.4.

(1) Collection of BSSID radio intensity information in the measurement area

↓

(2) Create radio intensity map for each BSSID (ID of wireless LAN base station)

↓

(3) Query position estimation using the radio intensity map

Fig.4 Flow of the proposed position estimation system

(1) Collection of BSSID radio intensity information in the measurement area: Wireless LAN radio intensity information is collected in the area where position detection is performed. Although an image data of the area is required, a simple floor guide may be used. Using a tablet PC with a wireless LAN communication function, measure BSSID, which is the identification number of the wireless LAN base station, and its radio wave strength multiple times (50 times in this research, about 3 minutes) for one point and take a median. They are combined with measurement position information on the drawing to construct a database. Wireless LAN BSSID information and radio intensity signal is obtained by "iwlist" command on Linux OS and Python script. Because a lot of data that is not required only with the result of the "iwlist" command is included, we made a program that records only the required ones. The position of each measurement point is input to the system using the image data of the area where position detection is to be performed.

(2) Create radio intensity map for each BSSID (ID of wireless LAN base station): A radio field strength map of the target area is created using the measured radio intensity and the position information on the image data. Although the radio wave intensity is originally given only by "points" on the actually measured drawing, the radio wave estimated intensity at places not observed on the drawing is linearly interpolated from the intensities of the observation points around them. In the convex hull area of the measurement points on the drawing, Delaunay triangulation with the measurement points as the seeds is performed, and the radio wave intensity is linearly interpolated to create the radio intensity map of the position detection area.

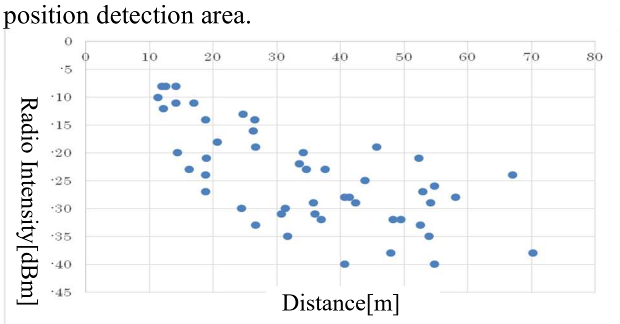


Fig.5 Relation between distance and the signal intensity.

Fig.5 shows an example of measurement results of the relation between distance from the LAN base station and received signal intensity. There is a lot of noise, but the radio intensity [dBm] and the distance are almost proportional in the range shown in the graph. For this reason, linear interpolation for the estimation of radio intensity is reasonable in the area between the measurement points as shown in Fig.6.

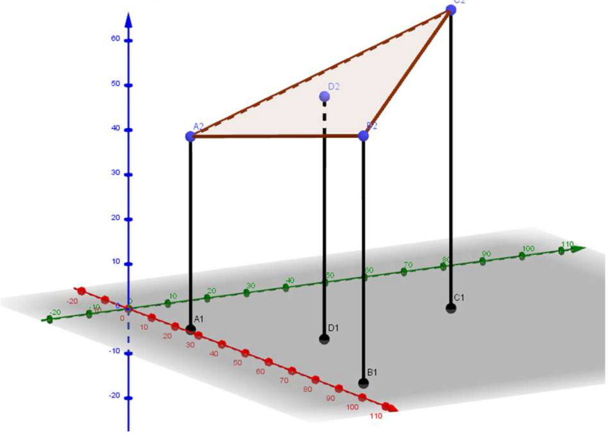


Fig.6 Interpolated signal intensity from the observed data.

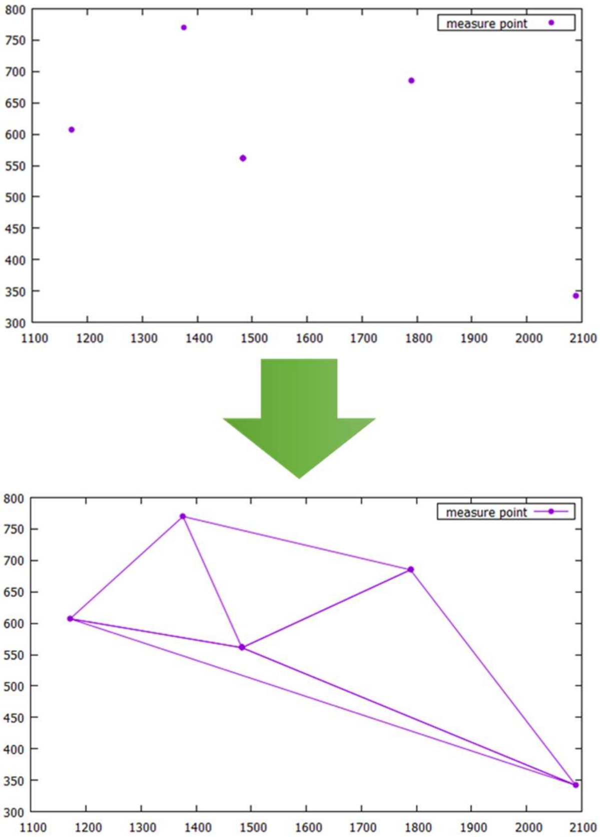


Fig.7 Delaunay triangulation with the observed points.

The vertical axis (blue) in Fig.6 is the radio wave intensity of a certain BSSID, the plane represented by the red and green axes is the position detection area, and each vertex of the triangle in the figure is the position where the observation was performed and its height represents measured radio intensity. A point inside the triangle in the position detection area is a query position, and its estimated radio intensity is given by interpolating the vertex height of the triangle. Fig.7 shows an example of Delaunay triangulation of the target area with the observed points as the seed points. Fig.8 shows an example of the correspondence between the map of the target area and the signal strength map of a certain BSSID.

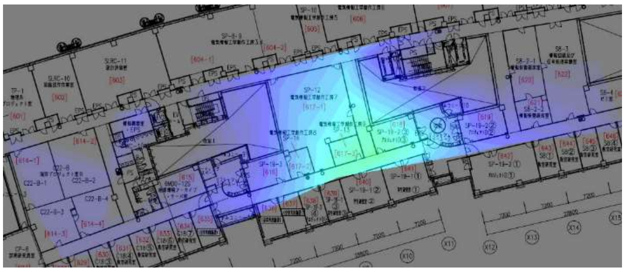


Fig.8 An example of a certain BSSID's intensity map.

(3) Query position estimation using the radio intensity map: Acquire BSSID and radio wave intensity observed by the terminal whose position you want to estimate, and use it as a query. The purpose of this system is to estimate the position of the query by comparing the radio intensity of the query with the BSSID radio intensity maps created in advance. The position estimation is realized by calculating a "similarity" of the query's radio signal for all meshes in the radio intensity map. The estimated query's location is given by a position where the similarity is getting largest value in the map. The simplest way to give "similarity" is calculating reciprocal of absolute value of the difference between the query's radio intensity and the intensity on the map for each BSSID. But it causes that the peak area of the similarity becomes flat as shown in Fig.10. The flat similarity peak is interfering with the estimation accuracy of the query position.

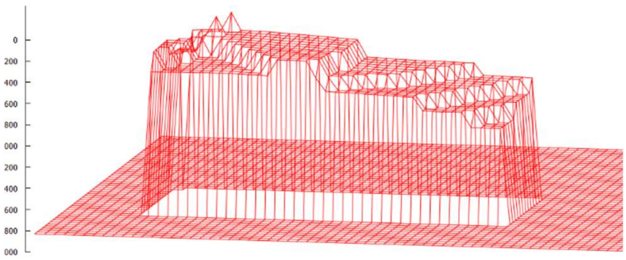


Fig.9 An example of simple similarity map by using reciprocal of absolute value of the difference between the query's intensity and the intensity on the map.

Therefore, we propose a new position estimation method from the radio intensity maps. Instead of simple calculating reciprocal of absolute value of the difference between the query and the intensity map, we use a new similarity function as shown in Fig.10. It is a piecewise linear function of the difference of the intensity between the query and the intensity map. Maximum value of the function is fixed to 1 where the difference is zero, and the value decreases as the absolute value of the difference increases. Notice that the end of the function has a negative value (Fig.10). This shape has the same effect as an edge filter in image processing. The similarity value is given by the following equations:

$$D_i = x_i(Q) - x_i(M) \quad (1)$$

$$S_i = \begin{cases} P_1 D_i + 1 & \text{, where } P_2 < D_i \le 0 \\ P_3 D_i + 1 & \text{, where } 0 < D_i < P_0 \\ 0 & \text{, otherwise} \end{cases} \quad (2)$$

$$S = \sum_{i=1}^{n} 10^{\left\{\frac{x_i(Q)+40}{P_4}\right\}} S_i \quad (3)$$

Where D_i is the difference between the radio intensity of the query and each BSSID's intensity on the map, S_i is the similarity of each BSSID, n is the number of BSSIDs, $x_i(M)$ is the radio intensity value at a certain location in the intensity map, and $x_i(Q)$ is the query's radio intensity observed at the place. The index i represents a certain BSSID. The parameters P_0, P_1, P_2 and P_3 shown in the equation (2) are characterizing the shape of the similarity function S_i , and are adjusted for the intensity map with P_4 shown in the equation (3). All the BSSID share the same similarity function. The parameter P_4 reflects the magnitude of the similarity function in proportion to each BSSID's radio intensity at the query location.

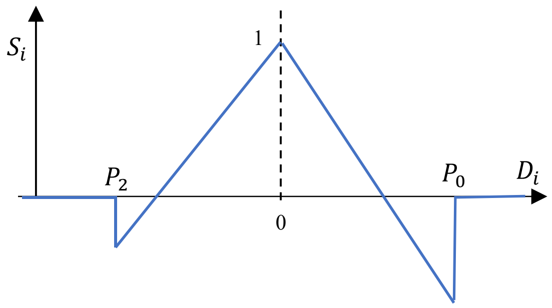


Fig.10 Similarity function S_i for a BSSID indexed by i.

The parameters of the similarity function are automatically adjusted by self-tuning, that is, each point in the convex hull region of the observation point group is selected one by one and regarded as a temporary query point, and the difference between the estimated positions and true positions of the temporary query points are used for the adjustment of the similarity function parameters. Our system is making use of Down-hill simplex method for the parameter adjustment. Note that the maximum value of the similarity S depends on the query signal intensity and the number of observed BSSID and so on. In our system, the value of the similarity S is normalized with the maximum value being 1 for convenience.

4. EXPERIMENTS

4.1 A RESEARCH BUILDING IN KYUSHU UNIV.

In order to examine the practicality of the proposed position detection system, an experiment was conducted on the 6th floor of Building W2 at Ito Campus, Kyushu University. We use Raspberry Pi 3 Model B+ with Raspbian OS as the wireless LAN device for observing BSSID radio intensity.

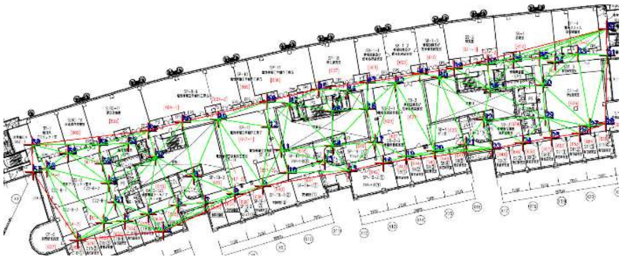


Fig.11 The floor map, observed points and Delaunay triangulation in the experiment at Kyushu University.

The target area is about 137[m] length and 30[m] width, the number of observed points is 62 (including query points), the average length of the edges in the Delaunay triangulation is 10.64[m] as shown in Fig.11. The number of observed BSSID is varied depending on the location, with a minimum of 20 and a maximum of 54. The average of the observed BSSID is about 30. The observed radio intensity is also varied, with a minimum -90[dBm] and a maximum of -31[dBm]. Fig.12 shows the optimized similarity function S_i , where $P_0 = -7.00, P_1 = 0.172, P_2 = 10.72$ and $P_3 = -0.030$. The parameter P_4 is also optimized as $P_4 = 27.89$ in this experiment. The average of the estimation errors over the inside of the convex hull of observation points is 2.456[m].

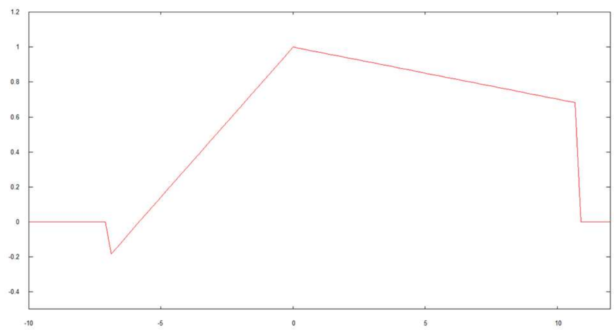


Fig.12 Optimized Similarity function S_i in the experiment.

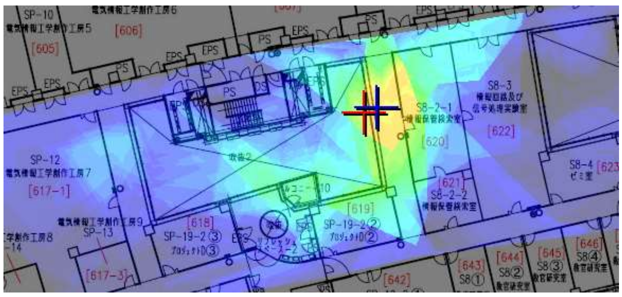


Fig.13 An example of the position estimation results. The blue cross in the figure represents the actual query position, and the red cross represents the estimated position. The estimation error is 1.22[m].

The data collection positions and the query positions are only the aisle in the building, and some position estimation accuracy can be obtained while reflection and attenuation of radio waves by the wall are expected. Fig.13 shows an example of the position estimation. In the estimation calculation, the data of the query position is removed from the database of the system. The estimation result is displayed as a contour of the similarity map, and the position that has the maximum similarity is the estimated position.

4.2 INSIDE A SMALL BLOCK ASSEBLY FACTORY IN A SHIPYARD

Our system is applied to inside of a factory building of assembly plant for small blocks equipped with wireless LAN networks. there are a large number of small steel plates and small blocks being transported by cranes in the factory building, and electric welding work etc. are performed. The target area of the experiment is about 43 [m] x 248 [m], and the wireless standard is 802.11g. The number of observed points is 28 (including query points), the average length of the edges in the Delaunay triangulation is 26.86[m] as shown in Fig.14. The number of observed BSSID is varied depending on the location, with a minimum of 17 and a maximum of 23. The average of the observed BSSID is about 20. The observed radio intensity is also varied, with a minimum -91[dBm] and a maximum of -58[dBm]. Fig.15 shows the optimized similarity function S_i , where $P_0 = -11.23, P_1 = 0.0.846, P_2 = 6.851$ and $P_3 = -0.395$. The parameter P_4 is also optimized as $P_4 = 20.65$ in this experiment. The average of the estimation errors over the inside of the convex hull of observation points is 12.3[m].

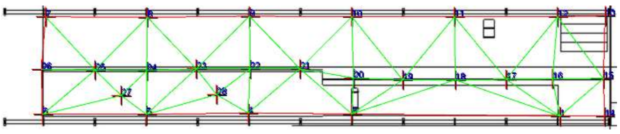


Fig.14 The floor map, observed points and Delaunay triangulation in the factory building.

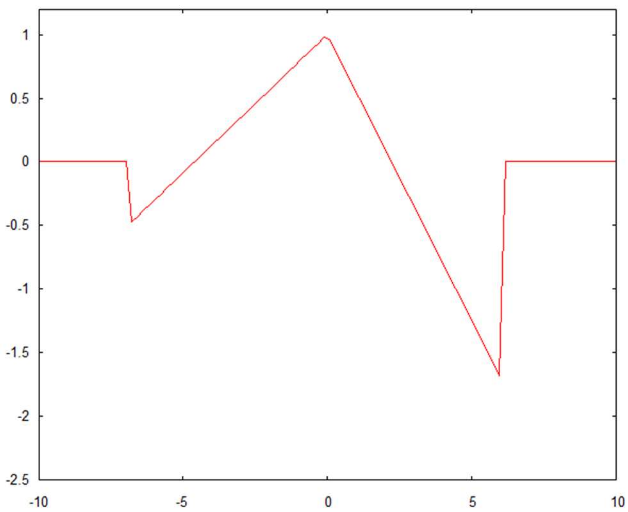


Fig.15 Optimized Similarity function S_i in the experiment.

Fig.16 shows an example of the position estimation.

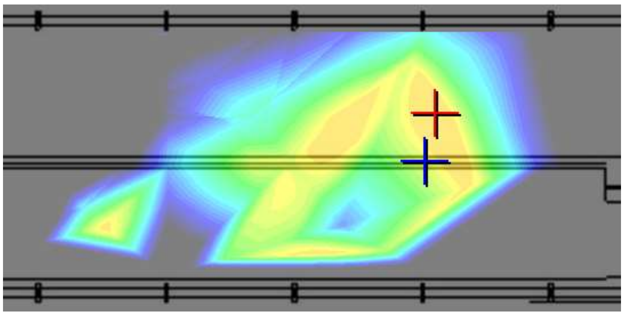


Fig.16 An example of the position estimation results. The blue cross in the figure represents the actual query position, and the red cross represents the estimated position. The estimation error is 7.90[m].

5. DISCUSSION

The estimation accuracy largely depends on the number of wireless LAN BSSIDs that can be received and the radio intensity. When the number of BSSIDs is small or the reception strength is weak, the estimation accuracy is degraded. In the experiment at the research building, 30 BSSIDs were detected per one measurement point, and the radio wave reception intensity was often 50-60 [dB], so the estimation accuracy was 2.456 [m]. On the other hand, in the factory, 20 BSSIDs were detected at one measurement point, but the radio wave reception strength was often as weak as 70-80 [dB], and the estimation accuracy was greatly reduced as 12.3 [m]. Unlike the experiment at the research building, there are also cases where a large steel plate is being carried immediately beside during radio wave measurement, which may be considered to be affected as noise.

The parameters P_0, P_1, P_2, P_3 and P_4 for the similarity function given in the equation (2) and (3) should be optimized as shown in Fig.12 and Fig.15. The best values of parameters also depend on the condition of the target. The proposed system can adjust the parameters automatically.

The number of measurement points and the distance interval must also be set appropriately in accordance with the number and intensity of BSSIDs that can be received. The measurement point must be selected so that the peak of the received radio wave intensity does not come inside the Delaunay triangle. Therefore, at the time of measurement, pay attention to the location of the antenna of the wireless LAN device installed in the building.

In this experiment, the wireless LAN device used for data collection of wireless LAN radio wave intensity was the same as the device used for radio wave observation of the query. It is necessary to investigate how the position estimation accuracy is affected when these devices differ.

6. CONCLUSIONS

In this paper, we investigate the location detection of the wireless terminal indoors in the factory where GPS cannot be used by using the existing wireless LAN infrastructure as it is without new capital investment. Although it was difficult to detect the position with high accuracy, it showed that it could be detected with an error of about 12 [m] in a factory, 2.45[m] in a research building equipped with wireless LAN networks, and showed the possibility of grasping the position of people and things in real time. The proposed system needs parameter adjustment for each target, but they are performed automatically.

This technology is patent pending by Kyushu University as Japanese patent application No.2017-96845.

7. ACKNOWLEDGEMENTS

The authors thank Oshima Shipbuilding Co., Ltd for the experiments in the factory building.

8. REFERENCES

1. Hitachi Systems, Ltd. ‘Wi-Fi real-time location information service’, http://www.hitachi-systems.com/solution/s002/musen_lan/wi-fi_location/.

2. WLAN_ASSOCIATION_ATTRIBUTES structure https://msdn.microsoft.com/en-us/library/windows/desktop/ms706828(v=vs.85).aspx

3. Fujita, S. Kaji, K. and Kawaguchi, N. 'A Wireless LAN Location Estimation Method Based on Gaussian Mixture Model', Journal of Information Processing Society of Japan Vol. 52 No. 3 1069--1081 (Mar. 2011 in Japanese).

9. AUTHORS BIOGRAPHY

Hajime Kimura holds the current position of Professor at the Department of Maritime Engineering, Kyushu University, Japan. His previous experience includes optimization in shipbuilding.

Nariki Iwauchi belongs to Tsuneishi Shipbuilding Co., Ltd., Japan.

Yuuichi Yoshida belongs to Kawasaki Heavy Industries, Ltd., Japan.