AN ESTIMATION METHOD OF WORKING AREA WITH RFID TECHNOLOGY

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Abstract

In this paper, the authors discussed the overview of a method for estimating working area for development of a monitoring system for labor management using RFID technology. RSSI (Receive Signal Strength Indication) data of RFID tag was obtained from readers set around the indoor space. An estimating model of the working area was prepared. The model had a range of the percentage of correctly classified from 61% to 95%. According to the result, the possibility of the monitoring system and the factors necessary to develop for practical were proposed.

Keywords: Working area information, RFID Technology, Neural network, Monitoring

1. Introduction

In order to make a project to a success, the layout planning of workers according to a working process and the adjustment based on the evaluation value of actual data are required for a site supervisor. The strict and effective control on labor is an important element for improvement in site productivity and safety. However, in this present, labor management is performed based on the total number of the worker a day collected by labor attendant in many cases, and the effect of the evaluation and adjustment to the site plan using the data is not expected largely. One of the reasons is that collection of the data which has required accuracy level in the now manual-operation data gathering process is difficult. We can control the working process progressively if we can collect where workers are working automatically.

The objective of this paper is to estimate working area of a worker with RFID technology, for developing a labor monitoring system. The working area is location information about the existence of a worker in a work place category.

The authors have suggested monitoring methods of a worker with RFID technology and evaluated the results, in other to clarify the technical problem due to using RFID for location system of a worker and to verify the applicability to labor management. [1] [2]

In this study, based on our previous study results, an estimation method of working area which aimed at the use to practical labor management was developed, and the effectiveness of the method was evaluated with experimental results. The experiment was performed in a test space which has the several floors without the partition similar to actual site circumstances, and the recognition of worker's location in the space where radio wave condition is complicated was carried out.

2. Estimation of working area

2.1 Site management based on working area information

A requirement for site management is doing proper manpower planning and materials procurement according to the project plan. Therefore, the measurement value of the work rate for understanding of goal attainment level has an essential role to play in the management. Performance observation is the receipt of sufficient information about the project to make an intelligent comparison of planned and actual performance. [3]

Installation procedures are carried out on the site, and each installation can be divided into task breakdowns such as attachment, processing, measurement, handling, movement and remove. Monitoring of the project progress in the level of task is required for the management adjust to a situation. However, in many cases, the management is performed based on the perfunctory information, and it causes a delay of action carried out to adjust the problem brought about in the process.

In this study, the authors suggested estimating the working area as a information for labor management. The working area is a space of construction site divided for each task, and it is defined as a resource for estimating the performance by connecting a worker to working area. That is, working area was set up as location information for collecting the actual achievement in a day.

The movement between working area can be presumed from two situations. The first situation is transfer in the attachment place following project progress, the occurrence frequency of that is one day or more. The second one is come-and-go between the task bases by the lay out plan, it is occurrence continuously. As shown in Figure-1, the movement has all directions on the basis of a working area, the worker who occupies each area changes according to a time series. For that reason, it is necessary to examine comprehensively the tasks, movement and time for collection of the location information.

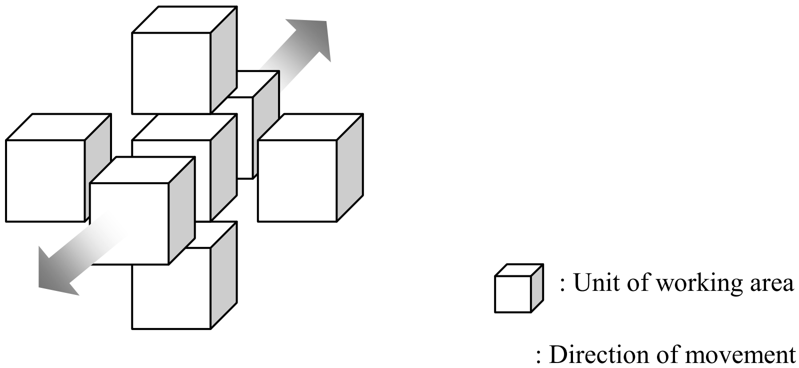


Figure 1 Movement of working area in the task progress

2.2 System design with RSSI data

The authors adopted the Radio Frequency Identification (RFID) technology in order to develop the estimation system of a working area. The working area where a worker is performing tasks is detected with the pattern of the Receive Signal Strength Indication (RSSI) collected using RFID readers. The readers are installed in each place of the site, and when a worker is in the recognition range of each readers, responds to a signal from the potable tag that transmit a worker’s ID. The pattern of RSSI changes with worker’s position, and working area is computed using the pattern. A lot of systems that compute the location of an object using RSSI calculate the distance from three or more readers to a tag, and output the 3-D position by triangulation method. However, in the construction site where the radio wave environment is instability, RSSI has measurement noise. Therefore, it was necessary for calculation of a working area to process measurement noise, we measured state distribution of the RSSI in the construction site space in which the readers were installed, and estimated working area using the pattern of the state distribution. The neural network was used for pattern analysis of RSSI.

The working area in a construction site to estimate is divided according to a management purpose, and RFID readers are installed in a place without the dead angle of radio wave. After installing readers, RSSI of each reader is collected as a neural network's training data set. The collection of data is performed moving a tag all over the working space in order that the pattern of an RSSI can be registered in all work postures and positions.

Moreover, the different RSSI value from the pattern of a training data comes out from the reasons of the influence of the noise which a machine generates around the frequency band of RFID, the mechanical trouble of RFID equipment, etc.. The authors developed two methods in order to maintain the reliability of an estimated result, even when an abnormal value comes out.

The first method is exclusion of the null data from input neurons, when RSSI is not detected at the time of neural network model training, and it reduces incorrect judging caused when recognition of the RSSI value of a tag in the detecting range fails.

The second method is smoothing of time series RSSI data based on a weighted moving average, when variation comes out in a time series by noise, and it performs estimation in the theoretical variation range of RSSI value in consideration of a worker's movement.

Estimation result of overall evaluation in the system is shown Figure-2. Two parts compose the system. One is an input to the network of RSSI data, and the other is the output of the estimated result of area. In the input of RSSI data, input data is divided into the Null RSSI and Valid RSSI, and moving average value is calculated with the multiplying factors.

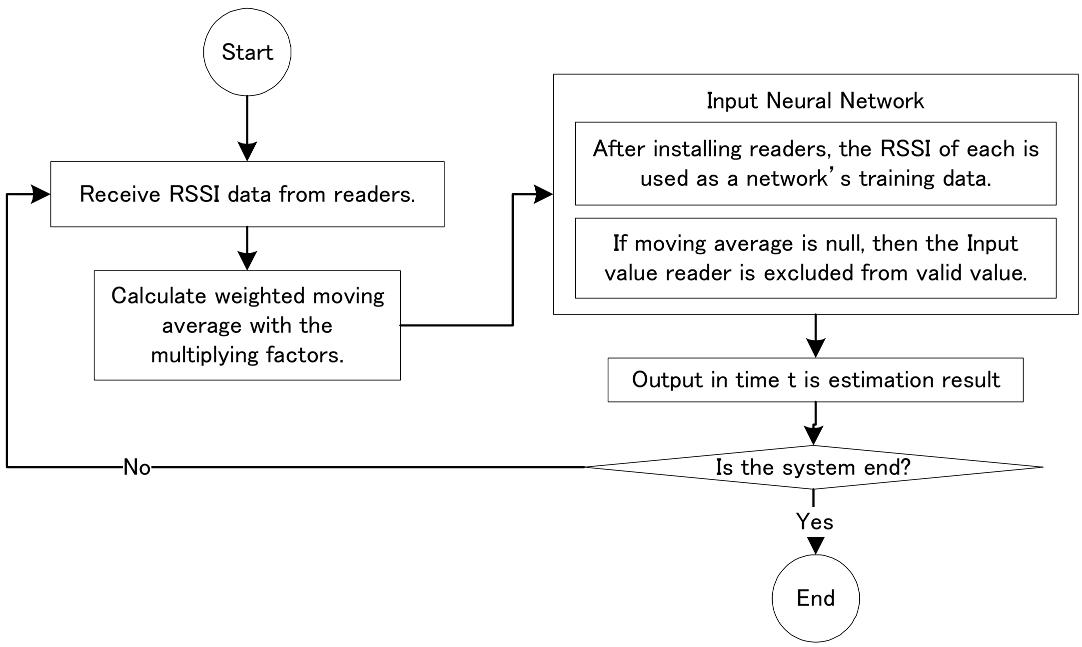


Figure 2 Working area estimating flow

3. Experiment results

3.1 Preparation for experiment

The authors performed the RSSI data of a RFID tag and actual area data of a person collection in order to develop the neural network model of an area estimation model. The data was obtained from a person working in the building with a RFID tag.

The RFID equipment used was composed of readers receiving signals from the tag and active tag with a battery embedded (Table-1). The operating frequency of the readers and tags is 315.1MHz and the detection range is approximately seven meters. The tag has power level of 500 μ V/m and signals with an interval of 0.5second.

Table 1. RFID specification

Reader	Size	152mm by 117mm by 30mm
	Weight	620g
	Frequency	315.1MHz
	Power	DC6v
Tag	Size	45mm by 38mm by 10mm
	Weight	10.3g
	Frequency	315.1MHz
	Power	CR2032

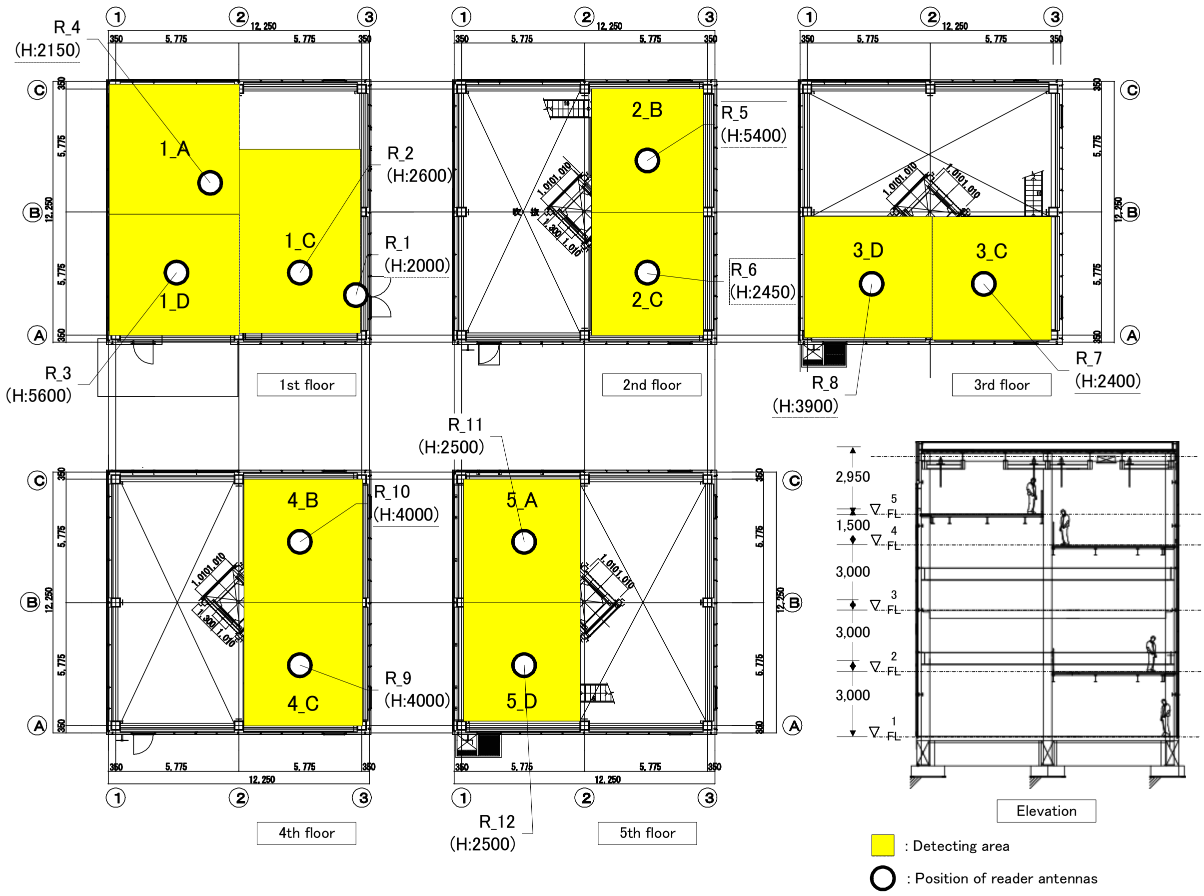


Figure 3. Detecting area and position of reader antennas

Reader antennas are set at 12 places in a building. The building has the size of 12m by 12m by 12m architectural volume and five floors. [4] The authors divided the floor into 11 areas and estimate each of areas as a location in which a person is present. Reader antennas attached to the floor beam are fixed with magnet. Moreover, the boundary between the areas in the same level does not have a partition wall. The range of the floor height of each area is 2.0 to 5.4m, and the distance from a floor level to an antenna installation side is various. Relationship of the readers and area plan are displayed in Figure-3. Figure-4 shows RFID reader, antennas and a person attached a tag used for the experiment.

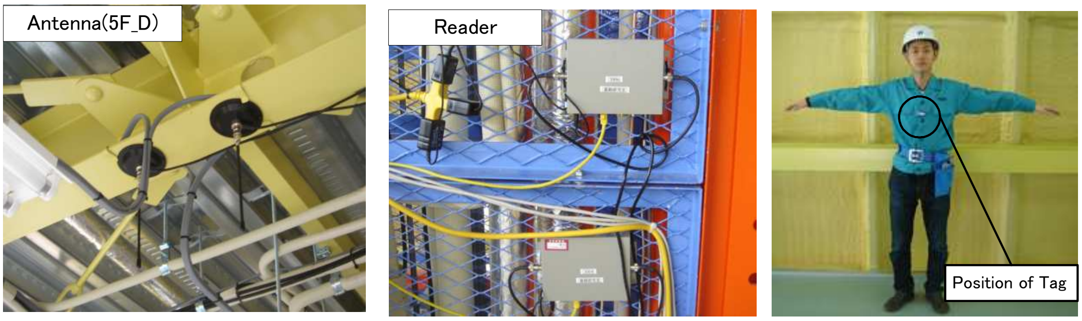


Figure 4. Equipments used for the experiment

3.2 Data collection

The authors collected the RSSI data for training and testing of neural network. The RSSI data of 12 readers in a time series was compiled for each 11 divided areas in the state of a person who installed the tag on the chest walking and turning. The position of tag was determined by displaying a tag in the breast pocket of one's shirt, and the height was about one meter from the floor.

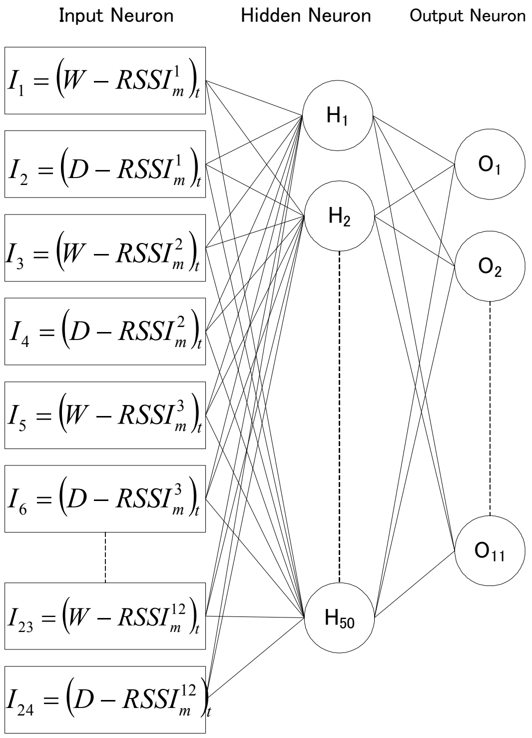
Table-2 shows the detail of collecting data. A total of three sets of data collecting experiments were conducted. In order to verify the estimated error by the difference in size of neural network training data, each data set were collected in a different unit. Also, the possible RSSI change occurring at the progress of time, the experiments were performed on each day. The size of collected data is the number of times which the 12 readers has recognized the person' tag RSSI of each area, the set_1 is 42,590 times (10,969 seconds), the set_2 is 30,024times (8,693 seconds) and the set_3 is 14,134 times (5,994 seconds). The detecting capability of a reader in the set_1 and set_2 which use two tags including a reserve tag was about 4 times per second, the set_3 which use four tags including three reserve tags was about 3 times per second.

Table 2. Rate for each data set

Set		Area											Total
		5_A	5_D	4_C	4_C	3_C	3_D	2_B	2_C	1_A	1_D	1_C	
set_1	Size	3962	3325	3894	3854	4100	4376	4737	4414	3457	2995	3476	42590
	Time (sec.)	1057	880	1021	1012	1048	1123	1201	1117	871	754	885	10969
	Rate (%)	9.3	7.8	9.14	9.05	9.63	10.3	11.1	10.4	8.1	7.0	8.2	100.0
set_2	Size	2736	2479	2379	2528	2331	2289	2691	2971	3117	3160	3343	30024
	Time (sec.)	811	735	698	744	676	669	778	848	894	893	947	8693
	Rate (%)	9.1	8.3	7.9	8.4	7.8	7.6	9.0	9.9	10.3	10.5	11.1	100.0
set_3	Size	1289	1271	1205	1235	1203	1286	1327	1237	1332	1253	1496	14134
	Time (sec.)	579	547	542	528	513	523	561	514	547	518	622	5994
	Rate (%)	9.1	9.0	8.5	8.7	8.5	9.1	9.4	8.8	9.4	8.9	10.6	100.0

3.3 Development of model

The effectiveness of the classification of the area was examined, using RSSI obtained from readers set at the site. The neural network model was designed in the three back-propagation network with standard connections. The divided data about 65% of the each area data was used for three training sets, and the output value is set to each 11 divided area. Figure-5 shows the design of neural network. The example of change of the RSSI value by moving average was displayed on the Figure-6.



Layer		Contents
Input	$I_{2n-1} = (W - RSSI_m^n)_t$	12 (Number of Reader) Weighted moving average of RSSI data of Reader−n in time series by Tag−m (form t−20 to t)
	$I_{2n} = (D - RSSI_m^n)_t$	12 (Number of Reader) Detectiing of Tag−m radio signal on Reader−n in time series (from t−20 to t). if RSSI=null then I=0, otherwise I=1.
Hidden		50
Output		11 (Number of detecting area)

(Index)

$$(W - RSSI_m^1)_t = \frac{n(RSSI_m^1)_t + (n-1)(RSSI_m^1)_{t-1} + \cdots + 2(RSSI_m^1)_{t-(n-1)} + (RSSI_m^1)_{t-n}}{n + (n-1) + \cdots + 2 + 1}$$

weight n=20

Figure 5. Design of neural network

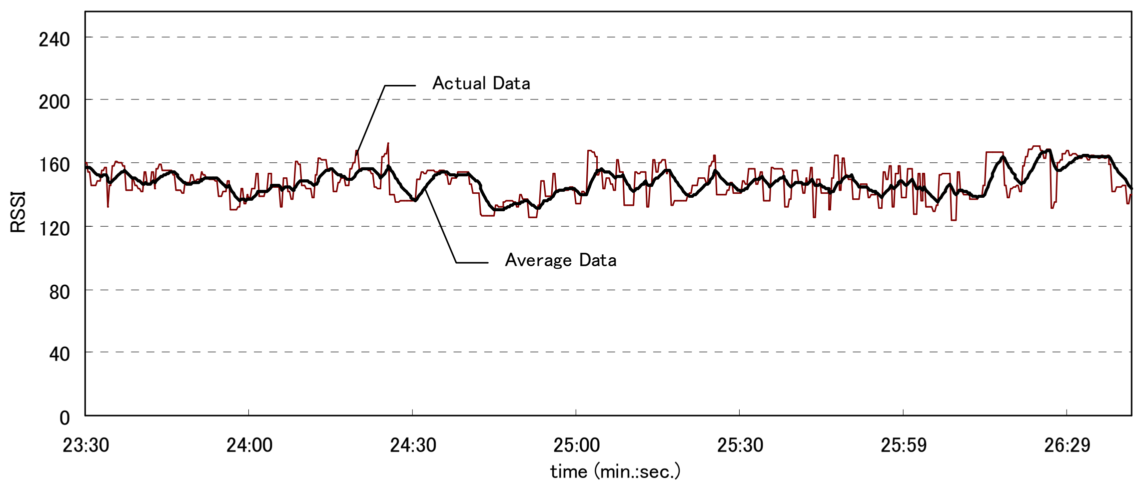


Figure 6. Comparison of actual data and moving average data (case of R_1 reader)

The authors calculated the area that the person's tag is in, using the three networks and predicting data of each set. As in Figure-7, the network models show a range of the percentage of correctly classified from 60.8% to 89.5% on the same data set. And classification of areas using set_3 network model which has 3,980 times training data resulted approximately lower then 20% the results of other two network models. From the result, it is necessary to plan the size of the data for neural network training in consideration of the error by lack of data collection position, slight movement of a tag condition and change of worker's body posture.

Moreover, the classification result which uses the training data of set_1 on the three predicting data set was 88.84%. (Table-3) The classification error occurred between the neighboring areas, expansion method of the area category must be considered in the lower estimating reliability from the result.

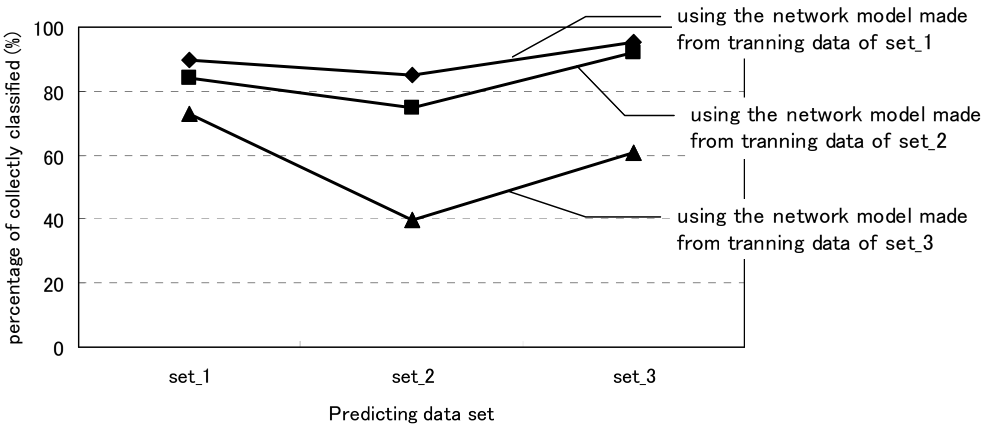


Figure 7. Comparison of the classification results between the network model and data set

Table 3. Classification results
(Training data: 67.2% of the set_1 data)
(Predicting data: 32.8%of the set_1, 39.5% of the set_2 and 34.5% of set_3 data)

Area		Original Group Membership											Total
		5_A	5_D	4_C	4_B	3_C	3_D	2_B	2_C	1_A	1_D	1_C	
Predicted Group Membership	5_A	2588	217	0	90	0	0	0	0	0	0	0	2895
		90.02%	8.59%	0.00%	3.71%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	9.47%
	5_D	278	2186	0	65	0	0	0	0	0	0	0	2529
		9.67%	86.57%	0.00%	2.68%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	8.27%
	4_C	0	122	2427	328	16	0	0	0	0	0	0	2893
		0.00%	4.83%	96.23%	13.53%	0.66%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	9.46%
	4_B	9	0	28	1941	0	0	0	0	0	0	0	1978
		0.31%	0.00%	1.11%	80.07%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	6.47%
	3_C	0	0	63	0	2122	167	0	0	0	3	0	2355
		0.00%	0.00%	2.50%	0.00%	86.97%	8.03%	0.00%	0.00%	0.00%	0.11%	0.00%	7.70%
	3_D	0	0	4	0	78	1913	0	0	0	0	0	1995
		0.00%	0.00%	0.16%	0.00%	3.20%	91.97%	0.00%	0.00%	0.00%	0.00%	0.00%	6.53%
	2_B	0	0	0	0	224	0	3242	336	725	4	0	4531
		0.00%	0.00%	0.00%	0.00%	9.18%	0.00%	98.57%	9.02%	24.72%	0.15%	0.00%	14.82%
	2_C	0	0	0	0	0	0	6	3349	102	80	0	3537
		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.18%	89.95%	3.48%	2.98%	0.00%	11.57%
	1_A	0	0	0	0	0	0	41	0	2082	242	0	2365
		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.25%	0.00%	70.99%	9.00%	0.00%	7.74%
	1_D	0	0	0	0	0	0	0	38	24	2303	64	2429
		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	1.02%	0.82%	85.65%	2.09%	7.95%
	1_C	0	0	0	0	0	0	0	0	0	57	3005	3062
		0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.12%	97.91%	10.02%
Total		2875	2525	2522	2424	2440	2080	3289	3723	2933	2689	3069	30569

Percentage of correctly classified: 88.84%

5. Conclusion

The authors examined the effectiveness of the RFID technology for determining the working area of workers in the construction site. In this paper, working area estimation method using RSSI data of RFID tag was developed, and neural network calculated the area that the person’s tag is in. The experiment in an indoor space was performed, classification result of 88.84% was obtained.

After the research, the authors found that movement in detection rate due to collecting data for training neural network, difficulties in set up area and readers for radio wave overlapping may result lower rate of classification. In order to apply RFID into working area estimating practically, improvement on data collecting method for network model training, and development of expansion method to the neighboring areas of a classification result are necessary.

It remain a major development issue how to collect the location information with detecting ID of materials and workers in study of the site management using RFID technology. However, even though the validity of the site management with the monitoring of location is recognized, practical use to an actual site is made difficult by restrictions of radio wave property. In this paper, based on the situation, a location information level available in labor management is defined as working area, and an effective estimation method was proposed.

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