A MONITORING METHOD OF PROJECT PROGRESS WITH RFID TECHNOLOGY

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ABSTRACT: In this paper, the authors explained the overview of a method for detecting location of worker for development of a monitoring system for project progress management using RFID technology. Data is the RSSI (Receive Signal Strength Indication) from RFID tag attached to the worker installing a rolling shutter, and was obtained from antennas and RFID readers set around the construction site. Neural network was done using RSSI collected and the area where worker is performing a task, and an estimation model of the working area was prepared. The network had a range of the percentage of correctly classified from 62% to 92%. The authors suggested the method to make estimate by using integrated networks prepared in respect of RFID readers, and showed the percentage of correctly classified of 84.3%. According to the result, the authors confirmed the possibility of the monitoring system with RFID technology, and mentioned the factors necessary to develop for further practical use.

Key words: RFID, Monitoring, Location Information, Project Progress, Neural Network

1. INTRODUCTION

In recent years, because of high demand of the improvement of the work productivity in the construction, the simplification of the working process at site and the modularization of material are developing. In such atmosphere, evaluation of works have been able to only be made by supervisors' physical observation, and it is impossible to understand concurrent performance all over the construction site at once.

We can collect the worker's performance data progressively if we can monitor how and where workers are working. Also, it would be easier to make analysis for site management, such as safety, productivity and quality control.

The objective of this paper is to detect location of worker with RFID Technology, for developing monitoring system inside ongoing building construction site.

The authors have suggested the method to measure the movement of a worker using 6DOF data and estimate the type of performance being done, and examined the effectiveness of the system [1].

A number of indoor location systems with wireless sensors have been used. Active Badge [2] is used diffuse infra-red technology to realize indoor location positioning. RADAR[3] and MoteTrack[4] are RF based systems for location and tracking users inside building, Cricket [5] and Active Bat [6] are two primary examples that uses the ultrasonic technology. SpotON[7] and LANDMARC[8] are location sensing systems using the RFID technology.

But these systems are operated under much favorable atmosphere for measurement where constant data reception is expected. On the other hand, in construction site, where full of radio wave interruption by temporary facilities such as scaffoldings, noise from electrical tools, fading of waves by metal obstacles and other hazards exist, receiving constant and reliable data from sensors is more difficult so the examination of effectiveness is required.

Further more, for the site under the construction of walls and ceilings, the location of sensors are not fixed and moved because of working progress, unlike finished building, therefore, selecting sensors with less calibration adjustments for relocation is necessary for this system.

In this method, the authors examined the factors relating to the location systems and adopted RFID Technology.

RFID (Radio frequency identification) is a technology that involves tags that emit radio signals and devices called readers that pick up the signal [9]. The method of identification is to store a serial number that identifies a worker, on a microchip that is attached to an RFID tag. The reader converts the radio waves reflected back from the RFID tag into identification and RSSI information that can then be passed on to computers.

In this study area and RSSI data is collected from worker installing a rolling shutter, then the neural network classified the area and examine the possibility of the system. Moreover, the authors analyzed the result and determined the factors necessary for RFID in the site management.

2. LOCATION SYSTEM DESIGN

Maintenance of quality, reduction of cost, adjustment of the delivery time, assurance of safety and health are the items of the important site management in the construction process. In order to manage such objects efficiently, accurately collection the concrete details of works and plan for solving the problem are indispensable.

However, in the present, management is performed based on the information collected by viewing of a supervisor in many cases, and it causes a delay of action carried out in order to solve the problem brought about in the process of construction. And the delay of action has a possibility of leading to useless consumption of resources. By collecting information effective in management using various sensors, it becomes possible to shorten the time of the delay of action.

The technology used for location sensing is as triangulation, scene analysis, and proximity. The distance from multiple reference positions calculated from the time of flight or the electric wave intensity, and the angulations are used for the geometric properties of triangles to compute object locations. [10]

In order to adopt sensor technology suitable for the location detection system of a construction site, the information in management needs to be clarified. As one of the information, the identification which each worker can always specify is needed in the wide range site. Moreover, the identification information specifies the worker who had the position presumed.

Because of construction work is a process which is creating the structure, fixing and installing a sensor in one place, and the places to install are unstable places, such as a scaffolding. In consideration of such environment, the width requirement of alignment accuracy and the simplicity of attachment are required for sensor equipment.

In addition, when installing equipment in a worker's body, the size which does not give trouble to treatment in a tool or material, and the form which is easy to install are necessary requirements for system.

The authors evaluated the sensors based on the elements taken up as a basis of selection required for the location system, and it proposed using RFID technology. There are many applications using individual recognition of RFID tags and leaders in the manufacturing industry, a distribution industry, etc.[11] The effect by using RFID for management of materials also in the construction site is expected. [12] In management of work, the monitoring of installation information, the input of situation report, etc. can be considered as a practical use field. However, if it becomes available to detect where a worker and a material are, the real-time and effective management extended to safety or labor will be available from the management restricted to the check of a work result.

Estimation of the position of the tag which emits radio signals is performed using the distances to the tag calculated with the RSSI of three or more receivers. Those distances are determined by the propagation times. But a receiver does not obtain at all times stable distance data. Because of the propagation time of a radio signal is changed by the noise which considers fading as a cause. There are reflection, refraction, diffraction, scattering, and interference as a factor which causes fading.

The authors classified location information into three categories, “Position”, “Area”, and “Gate”, according to the level applied to management. Each category has the calculation method and equipment suitable for computation.

The classification of location information is described below.

a. Position

The location information about a worker’s place in the site. The permissible error of estimate is assumed to be within a 1-meter radius.

b. Area

The location information about the existence of a worker in a work place category. The permissible error of estimate is assumed to be within a 2-meter radius.

c. Gate

The location information about the passage situation of the worker between areas. The permissible error of estimate is assumed to be within a 3-meter radius.

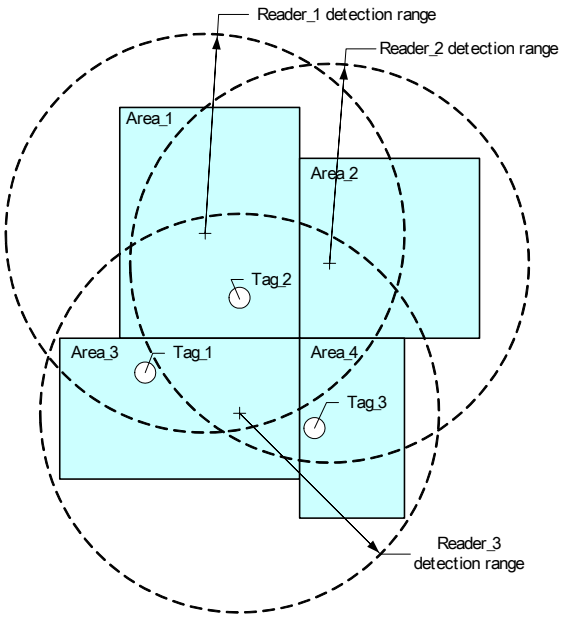

Figure 1. Pictures of readers and detection range

In this paper, the estimated method of the “Area” in the classified location information is explained using the active tag attached in a worker. First, the method limits the domain of the worker in the site, and divides the domain into area according to the contents of unit work. The installation positions of readers are decided according to the receiving capability of the radio wave of the tag which is present in the area. The equipment of a place to install is also the factor to which a position is made to adjust.

After installing leaders, the RSSI of each area is collected as a neural network's training data set, and a system for estimation is prepared.

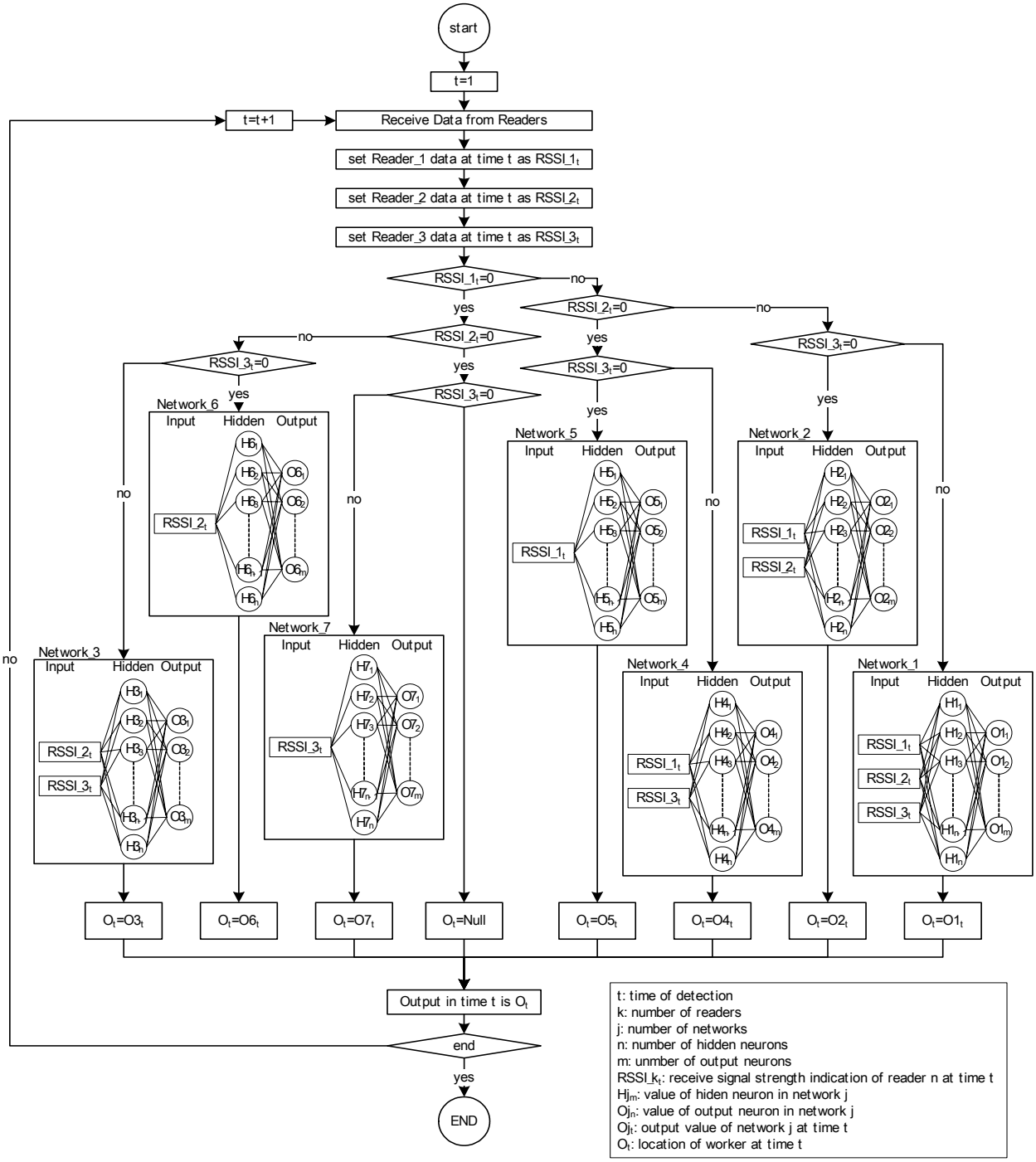

Figure2. Area estimating flow

The authors collected RSSI of the worker equipped with the RFID tag of each area of the site, developed neural networks using the data, and computed a worker's area from the comparison as a result of each network. Estimation result of overall evaluation in the system is shown in Figuer-2. The system is composed by two parts. 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, a network is selected with the combination of the data in time (t) included RSSI=0. In addition, when all RSSI data is 0, the estimated result of the time is null (Ot=Null).

3. EXPERIMENT RESULTS

3.1 Data Collection

The authors performed the RSSI data collection in order to develop the estimation model of the location system. The data was obtained from two workers installing a rolling shutter.

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 detection range of seven meters. The tag has power level of 500μV/m and signals with an interval of 0.5 second.

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

Readers are set at four places around the rolling shutter.

At first a reader (Reader_1) is placed at the top of assemble scaffoldings located in front of the rolling shutter to monitor the movement of the worker on the scaffoldings. Then the second and third readers (Reader_2, Reader_3) are set at the level of 1,800, 2,400mm apart of each other to monitor the movement of the worker at the floor. The last reader (Reader_4) is set beside the material storage area by the scaffoldings to monitor the movement around the storage area.

Readers directly attached to the scaffoldings are fixed with the plastic band. (Fig.2) The tag ID and RSSI data which readers obtained are sent to the data server through the wireless LAN converter. Relationship of the readers and floor plan are displayed in Fig-3.

Data collected for the research is working time, location of the worker, and tag RSSI data from readers.

Referring to the video tape, the site area is divided into four parts according to the task.

The classification of the area and the type of task is described below.

Area_1 : Worker picks up the material from the truck and move with material. Then he cut the material with a power saw.

Area_2 : Attaching rolling shutter parts and take measurement.

Area_3 : Carrying material to the storage area .

Area_4 : moving for adjusting scaffoldings, and preparing power supply.

Next the area and type of task is videotaped each second. RSSI from tag are collected as integer values between the range of 0 and 256, with minimum value and maximum of 0 and 256, respectively. When RSSI value is 0, it shows the situation either tag is out of readers' detection range or detection is not possible even if the tag is in the range. Tag is located nearest to the reader when RSSI value is 255.

Two tags are attached to each worker. In order not to interrupt the movement of worker nor disrupt detection, tags are attached in form of safety belt. Also, the possible RSSI change occurring at the change of direction, tags are attached at the both sides of the body.

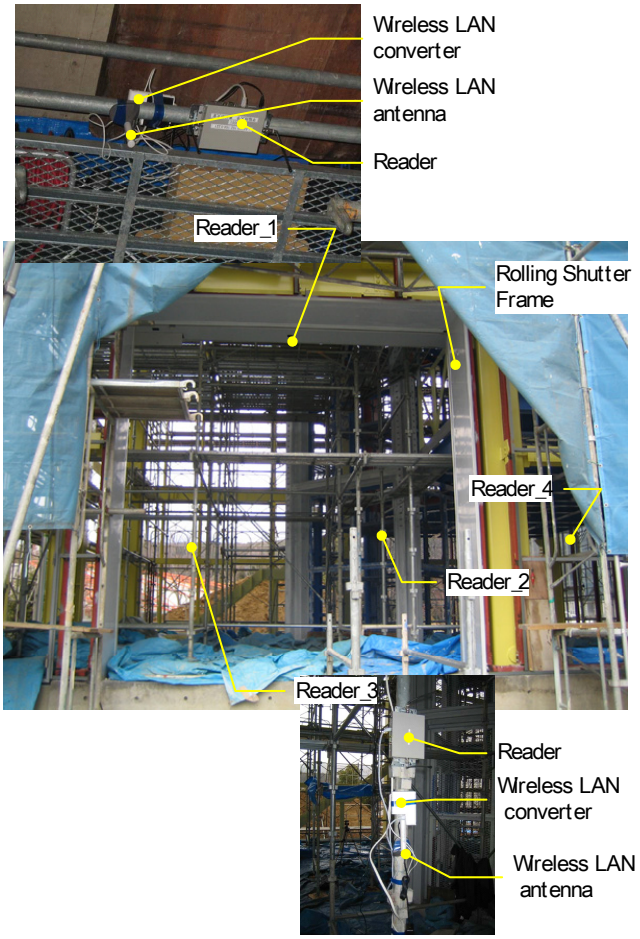

Figure 3. Pictures of readers

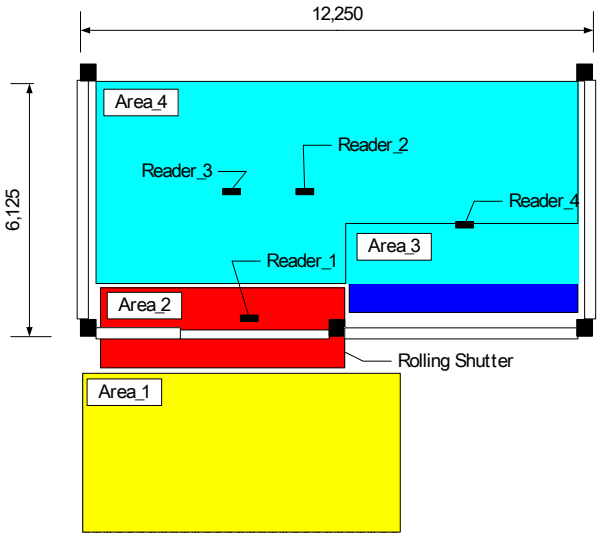

Figure 4. Detecting area of readers

3.2 Analyzing RSSI

The authors analyzed the relationship between tasks using RSSI statistics analysis.

At first, installation procedure is broken into 7 parts: Attachment, Processing, Measurement, Handling, Movement, Removal, Preparation, and amount of time required

is measured for each breakdown of tasks. (Table.2) Time needed for two workers was 678.6 minutes. Attachment, removal, and measurement are mainly performed in the Area_2, and took total of 204.5 minutes (29.9%). Processing was done in the Area_1, and because the materials are precut, time needed was just 21.3 minutes (3.1%). Handling and Movement are extended across the areas, and spent 192.3 minutes (28.3%). (Figure.5)

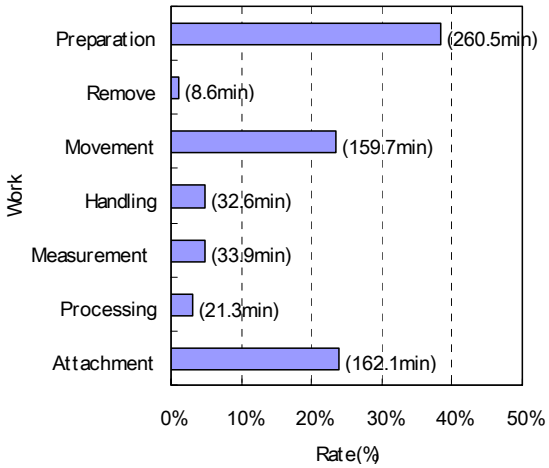

Figure 5. Time rate for each task

The average of tag RSSI was within the range of 160 to 180. By comparing worker-A and worker-B in the result, each tag RSSI average differs by about 10. The reason for the difference is due to the RSSI change in difference of position taken by the worker.

Then the authors analyzed the amount of time when RSSI was zero during the tasks, and checked how well tags were recognized while the work was done. For tags attached to the same worker, there are about 30% difference between two tags. In addition to that, Reader_1 set above the Area_2, where attachment was performed, the reader could not recognize 18-52% of the time spent, and for readers set above 1.8m from the floor of Area 3 and Area 4 had 50-98% of the time which RSSI was zero.

From the result, adjustment for the detection range among the reader is necessary in order to avoid detection rate decrease due to the relationship among the workers and readers, and to select the location where readers' waves spread evenly. Also, tags attached to the body should be increased and the locations must be selected to avoid them to be hidden for typical body position.

In addition to the relationship among readers and tags, use of power tools and welding machine, which may intervene operation frequency of RFID system, is the other factor affecting the detection ratio.

3.3 Development of model

The authors examined the effectiveness of the classification of the area performed, using RSSI obtained from readers set at the site.

Reader_4 was excepted from the system by the cause the percentage of the data of RSSI=0 was no less than 90%, and the network was prepared using RSSI of Reader_1, Reader_2, and Reader_3.The RSSI is maximum value of the two tags attached to the worker as input data, and eliminated value of zero for RSSI as irregular value. Networks are seven cases using the "each leader individually", "combination of the couple of leaders", "combination of the all leaders". (Table.2)

As for the rate of network data, network_1,Netwotk_4 and Netwotrk_7 in which reader_1 is contained are more than 20%. (Figure.6)

Table.2 Combination of RSSI set up the network

Network	Reader		
	Reader_1	Reader_2	Reader_3
Network_1	RSSI_1	0	0
Network_2	0	RSSI_2	0
Network_3	0	0	RSSI_3
Network_4	RSSI_1	RSSI_2	0
Network_5	RSSI_1	0	RSSI_3
Network_6	0	RSSI_2	RSSI_3
Network_7	RSSI_1	RSSI_2	RSSI_3

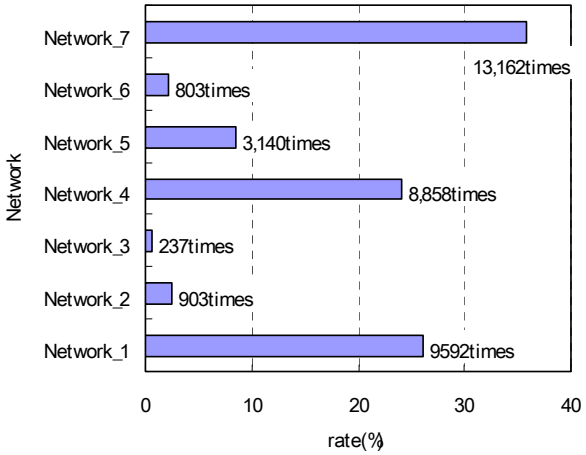

Figure 6. Rate for each network data

The randomly adopted 70% of the data from the each network was used for training sets, and the output value is set to from Area_1 to Area_4. The Neural network model is designed in the three-layered Back-propagation network with standard connections.

As in Figure-7, the networks show a range of the percentage of correctly classified from 62% to 92%. Classification of areas using Network_2 resulted 62%, approximately lower then 20% the results of networks. The Reader_2 is set in the location which the distance to the boundary Area_2 and Area_3 are almost the same, so that Area_3 was classified as in Area_2.

Moreover examination of the training sets of data models effectiveness using 30% of test sets was performed. Comparison between the data was made and the difference of result was 2%, confirming the effectiveness of the models.

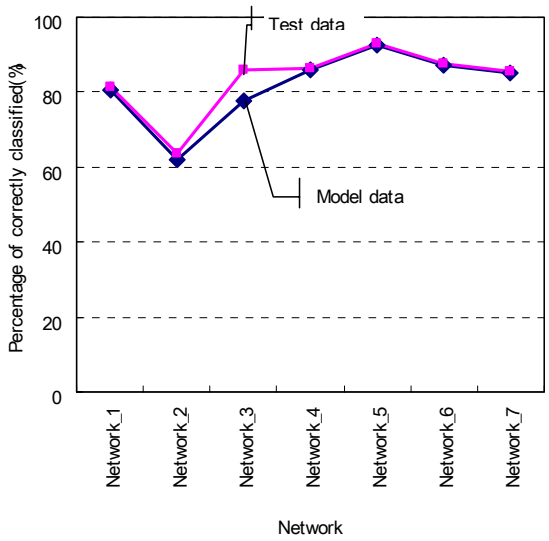

Figure 7. Comparison of the classification result between the model data and test data

The authors calculated the area that the worker is in, using the system. The classification result was 84.31%.(Table.3)

In result, adjustment among three readers using neural networks are made, so that the classification result was more than better than the result obtained from single reader. However, still the result suggesting neighboring area is classification error. Because of the result, interpolation of readers must be considered to select the location.

Table.3 Classification results

Area		Original Menbership				Total
		Area_1	Area_2	Area_3	Area_4	
Predicted Group Menbership	Area_1	1515	130	89	33	1767
		41.64%	0.45%	3.47%	1.73%	4.82%
	Area_2	2073	27640	1209	1216	32138
		56.98%	96.72%	47.10%	63.57%	87.58%
	Area_3	50	675	1240	122	2087
		1.37%	2.36%	48.31%	6.38%	5.69%
	Area_4	0	132	29	542	703
		0.00%	0.46%	1.13%	28.33%	1.92%
Total		3638	28577	2567	1913	36695
		100.00%	100.00%	100.00%	100.00%	100.00%

Percentage of correctly classified: 84.31%

4. CONCLUSION

The authors examined the effectiveness of the RFID technology for determining the location of workers in the construction site. In this paper, the authors developed location estimation method using neural network and performed the experiment in rolling shutter installation, classification result of 84.31% was obtained.

After the research, the authors found that decrease in detection rate due to site atmosphere, change of RSSI form worker at the same location but different body posture, difficulties in classifying area for readers' overlapping detection area may result lower rate of classification.

In order to apply RFID into location system in the construction site management, improvement on detection rate, devilment of noise reduction process of obstacles, and using multiple readers to divide data recording function are necessary.

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