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Noise Factors of RFID-Aided Positioning

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Abstract**—**In recent years, Radio Frequency Identification (RFID) is followed with interest by many researches, especially for the purpose of indoor positioning as the innate properties of RFID are profitable for achieving it. A lot of algorithms or schemes are proposed to be used in the RFID-based positioning system, but most of them are lack of environmental consideration and it induces inaccuracy of application. In this research, a lot of algorithms and schemes of RFID indoor positioning are discussed to see whether effective or not on application, and some rules are summarized for achieving accurate positioning. On the other hand, a new term "Noise Factor" is involved to describe the signal loss between the target and the obstacle. As a result, experimental data can be obtained but not only simulation; and the performance of the positioning system can be expressed substantially.

Keywords**—**Indoor positioning, LANDMARC, noise factors, RFID.

I. Introduction

NOWADAYS, data transfer is a vital segment in many aspects, for example the transportation, inventory management, security, etc. As a result, an efficient way of data transfer is indispensable especially when a lot of data need to be handled. RFID can provide wireless communication between reader and tags which are attached to the target objects. No matter the transmission rate, transmission distance, quantity of targets or reuse of tags etc., RFID has a better performance than the other wireless communication devices. Real world applications depending on automation are many [1]. Thus, RFID becomes a conspicuous technology in many industries.

Besides using for tracking or entrance guard, RFID has been used for indoor positioning. The RFID technology has the advantages such as contact-less, non-line-of-sight, multi-object recognition, long transmission range, scalability and promising cost-effectiveness, so it has been regarded as a viable and popular candidate for indoor location sensing [2][3]. LANDMARC is a very famous RFID indoor positioning method. Some of the other positioning methods are also referenced the algorithm of LANDMARC, but the accuracy of LANDMARC is not so high actually. Although a lot of researchers pay their efforts on the improvement of the precision level, most of them are lack of real application, may be just the simulation, or apply the methods in the clean room only. It indicates that the noises which affect the precise level deeply, have not been analyzed in detail, so the results are induced a lot of errors in the real applications.

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In this study, through the real experiments, but not only just the simulations, to understand the difficulties of applying RFID and discover the relationship between the noise and the signal of RFID. After they are known well, wider applications of RFID is achieved since the accuracy and precision level also can be enhanced, especially the indoor positioning which high accuracy and precision are required.

II. Literature Reviews

Nowadays, positioning is a vital function and many aspects are relied on it. Thus, a lot of positioning systems are investigated by different techniques:

A. Infrared

Infrared indoor positioning system was developed by Olivetti Research Laboratory; the accuracy of it is about 5 - 10 meters. The system is required to set up infrared receivers and every infrared was connected to a central server. By continuous emission signals from the portable infrared transmitter carried by the user, and the received signals will be delivered to the control server to estimate location of the user. [4]

B. Wi-Fi

The accuracy of it is about 3 - 5 meters. This system combines empirical measurements and signal propagation modeling in order to determine user location thereby enabling location-aware services and applications. [5]

C. Ultrasonic

The accuracy of it can be within 9 cm of their true position. This system uses an ultrasound time-of-flight measurement technique to provide location information. [6]

D. Bluetooth

Bluetooth operates in the 2.4-GHz ISM band. Depending on the deployment and the technique employed, the accuracy is about 2 - 15 meters. [7]

E. GPS

Global positioning system is one of the most successful positioning systems in outdoor environments. It is a space-based satellite navigation system that provides location and time information in all weather, anywhere on or near the Earth, where there is an unobstructed line of sight to four or more GPS satellites. [1]

F. RFID

Radio Frequency IDentification systems utilize electromagnetic wave to measure the position of the object. LANDMARC system and Spot ON system are two well-known RFID indoor positioning systems. [8]

Although there are a lot of positioning systems, they have some shortcomings. The infrared systems may result in cheap, compact and low power consumption, but the line of sight requirement and short range signal transmission are two major limitations. The difficulty of Wi-Fi systems is that the object being tracked must be supported by a Wave LAN NIC, which may be impractical on small or power constrained devices. About the ultrasonic, the ultrasound transceivers must be installed throughout the environment, and in order to be located, transmitter and receiver have to be in the line-of-sight. The costs of Bluetooth and GPS systems are too high, and the poor coverage of satellite signal for indoor environments decreases the accuracy of GPS and makes it unsuitable for indoor location estimation. On the other hand, RFID has a lot of advantages: size of tags, visibility, lifespan, performance in harsh environment, cost, reusability etc. According to RFID have a lot of advantages; a great many algorithms which based on RFID are explored to achieve indoor positioning:

LANDMARC, which is the ancestor of many positioning systems, requires signal strength information from each tag to readers and then bases on them to estimate the location of the tag. The weaker the signal is, the closer the tag is. It has three major advantages: First, there is no need for a large number of expensive RFID readers as reference tags are used and cheap. Second, the environmental dynamics can easily be accommodated since the reference tags are subject to the same effect in the environment as the tags to be located. Third, the location information is more accurate and reliable. [6]

VIRE, which is the next generation of LANMARC, introduces virtual tags to reduce the numbers of reference tag but also increase the accuracy. The gains of the virtual tags are obtained by linear interpolation algorithm, and then the unlikely positions are eliminated. It is more adaptive than LANDMARC in dynamic indoor scenarios. [9]

K.M. Yu, M.G. Lee, C.T. Liao and H.J. Lin [8] suggested to implement a RFID based real-time location-aware system in clean room and use the triangular positioning algorithm to estimate the location. The simulation results showed that it can take only1 minute to allocate the lost item.

P.W. Hsu, T.H. Lin, H. Chang, C.Y. Yen, Y.J. Tseng and C.T. Chang et al. [10] investigated optimal parameters in terms of reader and reference tag properties through computer simulations. The nearest neighbors number, effect of reader position layout, reference tag density and signal strength preprocessing are studied.

T. ZHANG, Z. CHEN, Y. OUYANG, J. HAO and Z. XIONG [11] proposed an improved locating algorithm which based on LANDMARC to improve the location precision by eliminating the dissimilarity among tags. The noise interference is considered by a noise standard deviation variable in the simulation, the result is closer to LANDMARC when the noise level is higher.

W. F. LI, J. WU and D. WANG [12] recommended using key reference tags to eliminate redundant reference tags of the system. This approach is based on the LANDMARC system.

The signal strength values of reference tags are collected in various environments first as the offline learning phase, and then the redundant reference tags are eliminated in the online positioning phase.

Y.H. HUANG, S.L. LV, Z.Y. LIU, W. JUN and S. JUN [13] studied the relationship between the nearest neighbor algorithm and the topology of reference tags used in LANDMARC. They proposed an optimal arrangement of reference tags and the simulation results showed that the new topology can provide better performance.

K.L. SUE, C.H. TSAI and M.H. LIN [14] proposed to divide the localization are into cells. Thus, reference tags become reference cell and the tags inside the cell as the reference tags. It can reduce the computational time and the simulation result showed that it also provides the high localization accuracy as LANDMARC.

A. Silva and S. Concalves [15] suggest a revised method for LANDMARC. Their algorithm can reduce the need for blind searches by automatically reporting to users a second estimate of the possible area in which the target object could be located. The simulation results showed that the overall location performance is boosted by up to 96.66%.

G.Y. JIN, X.Y. LU and M.S. PARK [16] proposed to use average error range to revise the result of LANDMARC. Thus, the higher locating accuracy can be reached and the computing load is reduced.

S. JAIN, A. Sabharwal and S. Chandra [17] recommended eliminating the reference tags which are far away or blocked by obstacles. And the signal loss function is added a variable to adjust the noise level for different materials between the reader and tags.

X. ZHANG, J. PENG and X. CAO [18] provided a method to improve VIRE. Lagrange and Newton are used to replace linear interpolation algorithm. The results showed that Newton interpolation not only makes the result more accuracy, but also cost less calculation time.

X.J. JIANG, Y. LIU and X.L. WANG [19] suggested to utilize the strategy of putting the tracking tag and its k nearest reference tags in a set, then repeating to calibrate the target coordinate by the error corrections which obtained by members of this set. The calibration will continue until the tracking tag's coordinate tend to be a stable value.

R.C. CHEN and S.L. HUANG [20] proposed to obtain the cross section area of the RSS values, and then use the tags inside as the reference tags, finally using arithmetic mean to calculate the location values. A preliminary experiment proves this method has a better precision than LANDMARC system.

These methods have their own advantages and disadvantages. In the Section V, a further discussion is provided and some rules are summed up for applying RFID indoor positioning system in real environment.

III. Experimental Details

In this study, some experiments are done for different purposes and they are interpreted in detail below. HK-RFID

EMPRESS 2.4GHz Active RFID Reader is selected for this research and the system is programmed by C# and SQL.

A. LANDMARC

The LANDMARC algorithm has been tested at the CAD CAM Laboratory in the University of Macau, which is a place that full of machines and tools as Fig. 1. Thus, the performance of LANDMARC algorithm under noise environment can be obtained, but not only in the clean room or simulations.

Twelve reference tags and four neighbor tags are used, the distances between the reference tags are 80cm and the experiment has been repeated for twenty times.

B. Angle of antenna

For the purpose to understand the relation between the angle of the antenna of the RFID reader and the signal, this experiment is done in a clean room and is shown in Fig. 2, and the targets are one reader and one tag only.

The angle of the antenna and the distance between the tag and reader are adjusted, the signal distribution with various distances to the reader under different angles of the antenna is obtained.

C. Height of tag

For the purpose to understand the relation between the height of the tag relative to the antenna of the reader and the signal, this experiment is also done in a clean room and one reader vs. one tag.

The height of the tag relative to the antenna of the reader is adjusted as shown in Fig. 3, the height of the insulating cushion is 5cm as the height of the antenna is 10 cm. The signal distribution with various distances to the reader under different heights of the tag is obtained.

D. Effect of Wi-Fi

The frequency of Wi-Fi and the EM wave of the RFID reader is the same. For the purpose to see if they will affect each other or not, the experiment is done under Wi-Fi environment and non Wi-Fi environment.

For the Wi-Fi environment, the Wi-Fi router is turned on and close to the reader. For the Wi-Fi environment, all the Wi-Fi devices in the laboratory are turned off. Thus, the signal distribution with various distances to the reader under different Wi-Fi environments is obtained.

E. Effect of brick

For the purpose to see the influence of a wall to the signal, a brick acts as a wall in this experiment. Since the frequency of Wi-Fi signal is the same to the signal of the RFID reader, and the reader also has a Wi-Fi antenna, the Wi-Fi signal of it is blocked by the brick and is checked by a software WirelessNetView.

F. Effect of CNN machine

For the purpose to understand the relationship between metals and the signal, this experiment is done besides the CNN machine, which is one of the mainly metallic obstacles in the CAD CAM laboratory. Thus, the signal distribution with various distances to the reader under different distances to the CNN machine is obtained.

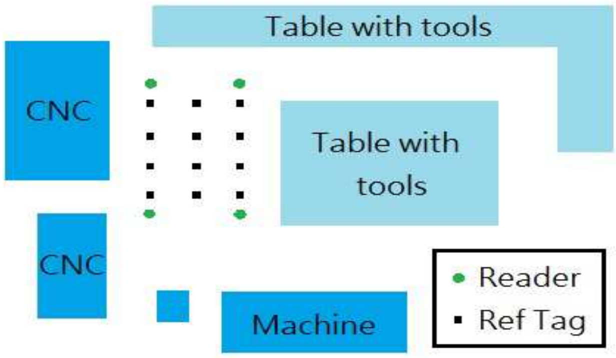


Fig. 1 Layout of CAD CAM Laboratory

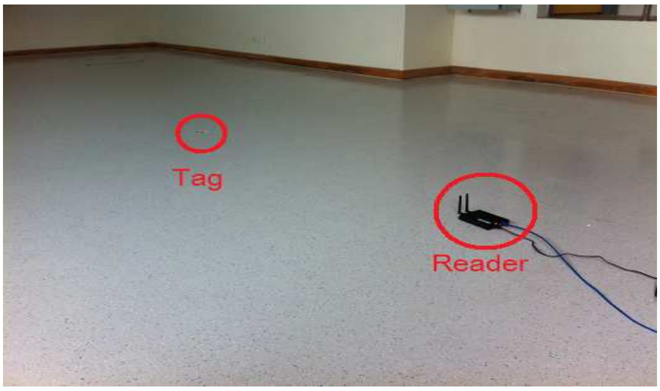


Fig. 2 The clean environment for the experiment

Fig. 3 The setup of the height of tag experiment

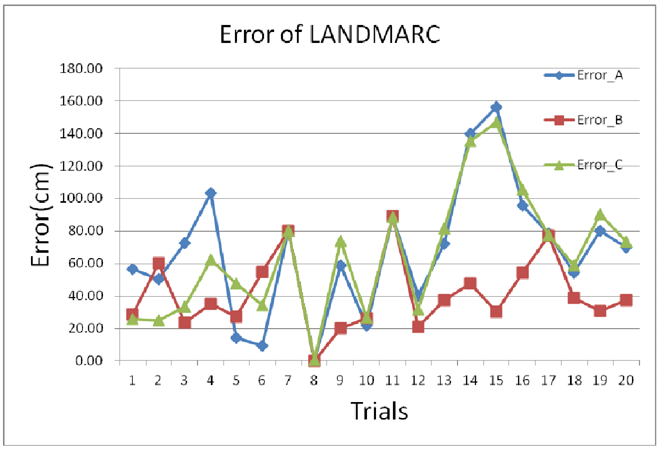
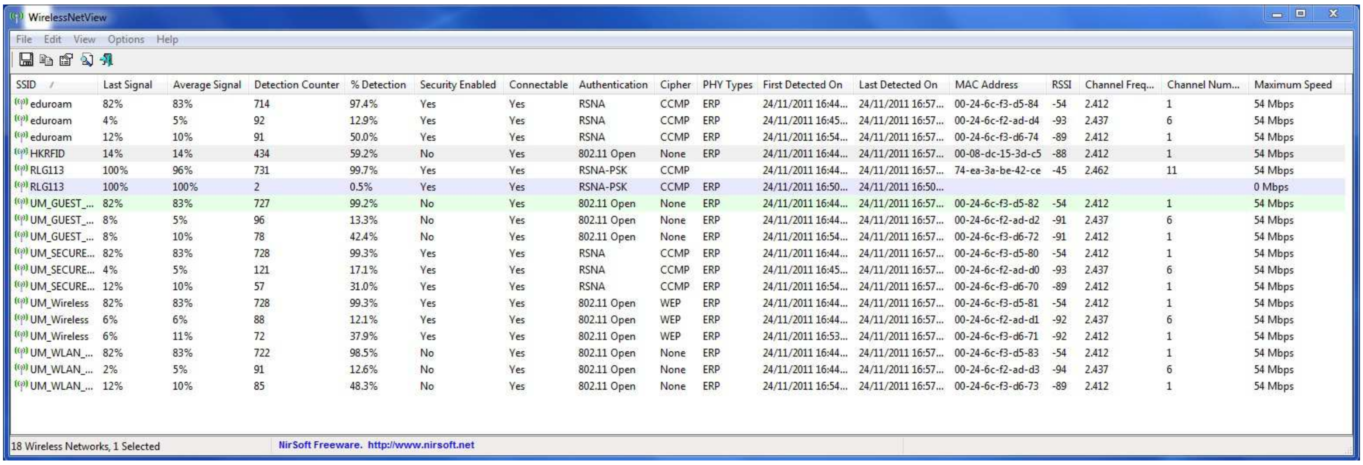


Fig. 4 The error of LANDMARC algorithm



SSID	Last Signal	Average Signal	Detection Counter	% Detection	Security Enabled	Connectable	Authentication	Cipher	PHY Types	First Detected On	Last Detected On	MAC Address	RSSI	Channel Freq...	Channel Num...	Maximum Speed
eduroam	82%	83%	714	97.4%	Yes	Yes	RSNA	CCMP	ERP	24/11/2011 16:44...	24/11/2011 16:57...	00-24-6c-f3-d5-84	-54	2.412	1	54 Mbps
eduroam	4%	5%	92	12.9%	Yes	Yes	RSNA	CCMP	ERP	24/11/2011 16:45...	24/11/2011 16:57...	00-24-6c-f2-ad-d4	-93	2.437	6	54 Mbps
eduroam	12%	10%	91	50.0%	Yes	Yes	RSNA	CCMP	ERP	24/11/2011 16:54...	24/11/2011 16:57...	00-24-6c-f3-d6-74	-89	2.412	1	54 Mbps
HKRFID	14%	14%	434	59.2%	No	Yes	802.11 Open	None	ERP	24/11/2011 16:44...	24/11/2011 16:57...	00-08-dc-15-3d-c5	-88	2.412	1	54 Mbps
RLG113	100%	96%	731	99.7%	Yes	Yes	RSNA-PSK	CCMP		24/11/2011 16:44...	24/11/2011 16:57...	74-ea-3a-be-42-ce	-45	2.462	11	54 Mbps
RLG113	100%	100%	2	0.5%	Yes	Yes	RSNA-PSK	CCMP	ERP	24/11/2011 16:50...	24/11/2011 16:50...					0 Mbps
UM_GUEST_...	82%	83%	727	99.2%	No	Yes	802.11 Open	None	ERP	24/11/2011 16:44...	24/11/2011 16:57...	00-24-6c-f3-d5-82	-54	2.412	1	54 Mbps
UM_GUEST_...	8%	5%	96	13.3%	No	Yes	802.11 Open	None	ERP	24/11/2011 16:44...	24/11/2011 16:57...	00-24-6c-f2-ad-d2	-91	2.437	6	54 Mbps
UM_GUEST_...	8%	10%	78	42.4%	No	Yes	802.11 Open	None	ERP	24/11/2011 16:54...	24/11/2011 16:57...	00-24-6c-f3-d6-72	-91	2.412	1	54 Mbps
UM_SECURE...	82%	83%	728	99.3%	Yes	Yes	RSNA	CCMP	ERP	24/11/2011 16:44...	24/11/2011 16:57...	00-24-6c-f3-d5-80	-54	2.412	1	54 Mbps
UM_SECURE...	4%	5%	121	17.1%	Yes	Yes	RSNA	CCMP	ERP	24/11/2011 16:45...	24/11/2011 16:57...	00-24-6c-f2-ad-d0	-93	2.437	6	54 Mbps
UM_SECURE...	12%	10%	57	31.0%	Yes	Yes	RSNA	CCMP	ERP	24/11/2011 16:54...	24/11/2011 16:57...	00-24-6c-f3-d6-70	-89	2.412	1	54 Mbps
UM_Wireless	82%	83%	728	99.3%	Yes	Yes	802.11 Open	WEP	ERP	24/11/2011 16:44...	24/11/2011 16:57...	00-24-6c-f3-d5-81	-54	2.412	1	54 Mbps
UM_Wireless	6%	6%	88	12.1%	Yes	Yes	802.11 Open	WEP	ERP	24/11/2011 16:44...	24/11/2011 16:57...	00-24-6c-f2-ad-d1	-92	2.437	6	54 Mbps
UM_Wireless	6%	11%	72	37.9%	Yes	Yes	802.11 Open	WEP	ERP	24/11/2011 16:53...	24/11/2011 16:57...	00-24-6c-f3-d6-71	-92	2.412	1	54 Mbps
UM_WLAN_...	82%	83%	722	98.5%	No	Yes	802.11 Open	None	ERP	24/11/2011 16:44...	24/11/2011 16:57...	00-24-6c-f3-d5-83	-54	2.412	1	54 Mbps
UM_WLAN_...	2%	5%	91	12.6%	No	Yes	802.11 Open	None	ERP	24/11/2011 16:44...	24/11/2011 16:57...	00-24-6c-f2-ad-d3	-94	2.437	6	54 Mbps
UM_WLAN_...	12%	10%	85	48.3%	No	Yes	802.11 Open	None	ERP	24/11/2011 16:54...	24/11/2011 16:57...	00-24-6c-f3-d6-73	-89	2.412	1	54 Mbps

Fig. 5 Wi-Fi signal with a brick

IV. Result

A. LANDMARC

The error (Fig. 4) is obtained by calculating the distance between the true position and the calculating position. And there are three cases: Case A is to choose the four neighbor tags based on RSS signals, Case B is to choose the four neighbor tags by selecting the nearest four reference tags manually and Case C is to select all the reference tags as the neighbor tags.

B. Angle of antenna

The angle of the antenna is adjusted to be horizontal (Fig. 6) and vertical (Fig. 7), then the signal distributions are obtained. Both of the curves tend to diminish, and also oscillate.

C. Height of tag

In the previous experiments, tags are on the floor to be read. And in this experiment, after the tag is supported, the signals are received better and are shown in Fig. 8.

D. Effect of Wi-Fi

From the Fig. 5, a lot of Wi-Fi devices are detected. Although the Wi-Fi devices in the laboratory are turned off, Wi-Fi devices are around us. Thus, the influence of Wi-Fi can't be fully excluded, and the performances of the Wi-Fi devices are turned off or not are the same.

E. Effect of brick

By using the WirelessNetView, the strength of the signals are obtained as below.

Before blocked with the brick:

- Last Signal : 18%
- Average Signal : 19%
- RSSI : -86

After blocked with the brick:

- Last Signal : 20%
- Average Signal : 19%
- RSSI : -85

As a result, the influence of the brick is indistinct.

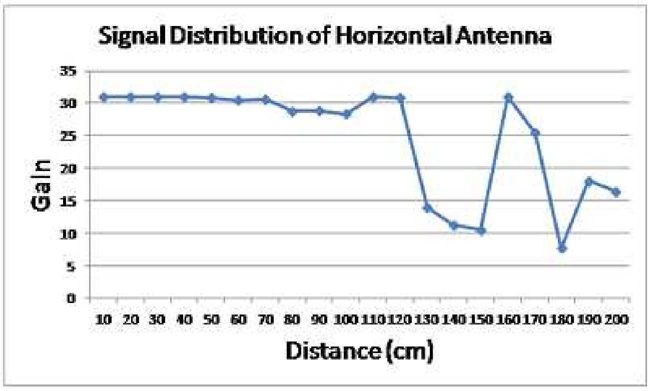


Fig. 6 Signal distribution of horizontal antenna

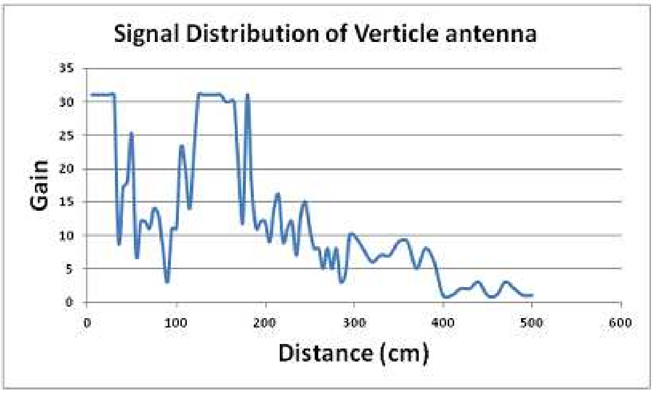


Fig. 7 Signal distribution of vertical antenna

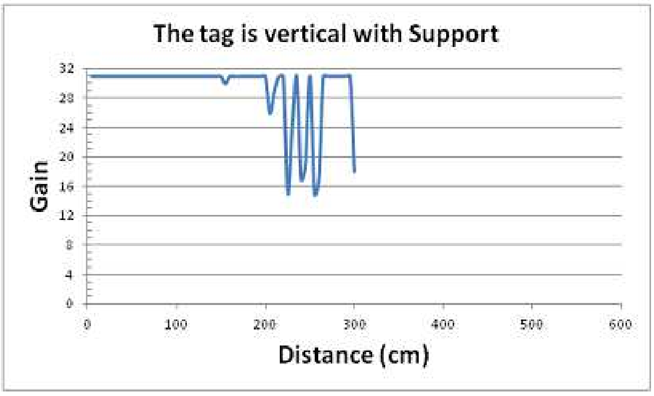


Fig. 8 Signal distribution under the tag is vertical with support

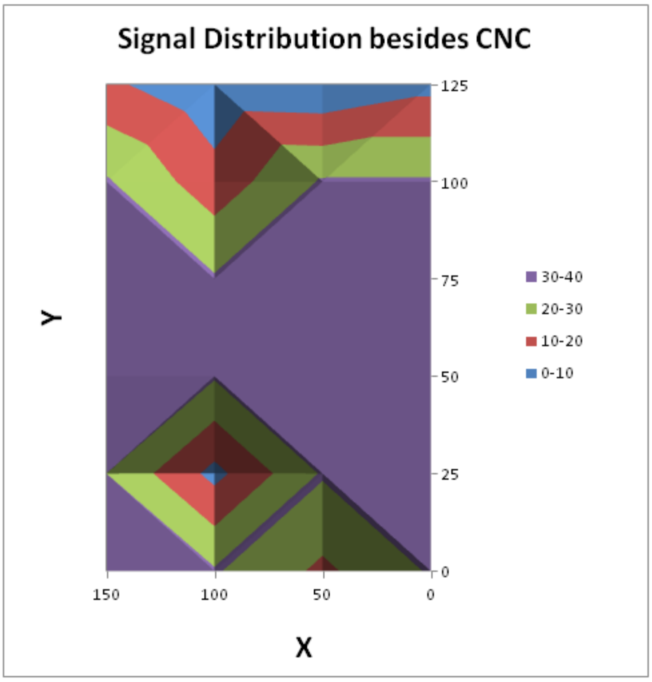


Fig. 9 Signal distribution besides CNC

F. Effect of CNN machine

RFID tags are put besides the CNC machine, and the reader is put close to the origin. The signal distributions of the tags are shown in Fig. 9. The gain of the reader is from 1 to 31, when the tag is far away, the gain is close to 1; when the tag is near the reader, the gain is close to 31.

The area which close to the origin should have a larger gain and the area that is far away from the reader should have a smaller gain. For the further part, the gain decreases normally, but for the closer part, the gain decreases abnormally, the signals are affected by the CNC machine.

V. Discussion

As a lot of methods are reviewed, some common points of them are summarized:

1. Most of them use simulation as a tool to prove their improved methods. It is hard to reflect the noises in the environment. As a result, the performances of the new methods may totally different when they are applied in the real environments.
2. Most of the new methods are lack of noise consideration. Although some experiments are done, they just ignore the noises. Thus, when these methods are applied in the noise environment such as workshop, office, etc., the signals are affected by the obstacles and metals.
3. Some methods are concerned about the noise, but they assume the noises distribute averagely. Unfortunately, the noises distribute irregularly. Therefore, these methods are still ineffective when they are applied in the real situations, and most of them just use simulations.

LANDMARC algorithm is easy to be implemented, so a lot of methods are referred to it. Based on the algorithm, some rules are summed up:

1. *Linear Signal Distribution*

   As the LANDMARC algorithm is used the weights of the reference tags to estimate the position of the target, the linear property of the signal distribution is very important. The more linear the signal distribution is, the better the performance is. In the real environment, it is hard to obtain the linear signal distribution directly. Thus, noise factors are necessary.

2. *Noise Factors*

   The average noise assumption is not suitable for the real environment, and the signal loss equation focuses on the signal between the tag and the reader only, the noises which around the tags are ignored. As a result, noise factors are used to express the signal loss around an object, it won't be changed even the position of the object is changed. This information can be saved as a library for the system to use.

3. *Computational Algorithm*

   The searching time is mainly affected by the computational algorithm of the system. Except the LANDMARC algorithm, how to collect the signal efficiently is also very important. Not only reducing the searching time, but also the experiment time.

About the experiment part, the LANDMARC algorithm is proved that it is not suitable for using in a noise environment directly. It is found that the antenna is effective to the signal distribution, no matter the orientation or the height. It is related to the property of antenna, as Fig. 10 shown. The horizontal plane that the middle point of the antenna exists in is the best position to receive the signal, so a support is used to increase the height of the tag to test this property. On the other hand, the normal line of the tag is more effective to the result when it is perpendicular to the direction of the antenna, which can increase the receiving area to reach the optimal signal receiving plane of the antenna. The Wi-Fi problem can't be eliminated fully and the influence of walls is relatively less than that of metals from the machines.

These property and influences can be used to adjust the performance of the system to achieve linear signal distribution and involve noise factors. About the further work, the overlaps of the noise factors can be studied, or even more noise factors can be involved.

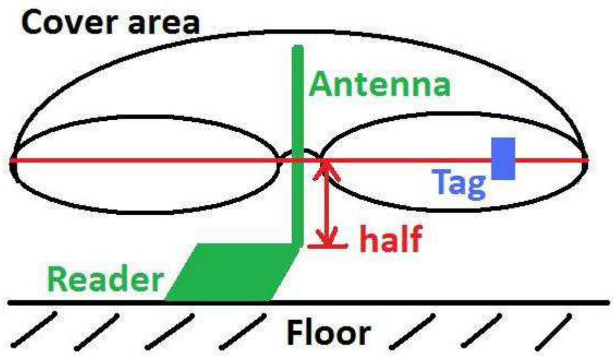


Fig. 10 Property of an antenna

VI. Conclusion

The main contribution of this study is that the rules of applying RFID indoor positioning system in the noise environment are established. Linear signal distribution and noise factors are vital to the accuracy of the positioning system, and also the efficiency of the system is affected by the computational algorithm of data collecting. Therefore, the further work is to study more noises which affect the RFID signals for enhancing the precision level of the positioning system.

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