Development of User-friendly GUI for Indoor Localization using RFID Passive Tag

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***Abstract*—Radio frequency identification (RFID) is an automatic identification technology that enables tracking of people and object. In this paper, passive RFID tag is used for indoor localization. Passive RFID tag has many advantages i.e.,cost-effective, relatively small and its endurance.This paper proposes simulation of indoor localization usingself-created Graphic User Interface (GUI) to apply the RFID-based localization using fingerprint technique.In this paper, Maximum number of intersect tags and Maximum and 2nd Maximum number of intersect tags are deployed as pattern matching algorithm. For this technique,the database of fingerprint is obtained fromID information of the tags. The maximum number of intersect tag will be used as the justification of measured position of the target node.The estimated error location is obtained from the location estimation result compared with fingerprint location in the database. Theaverage error in the estimation result for both techniquesis approximately 21 cm. From the results, we can conclude that our proposed method can be applied in real situation.**

***Keywords*-Indoor localization, RFID passive tag,Fingerprint technique.**

I. INTRODUCTION

The indoor localization has been a vital research topic in applications of wireless networks. Examples of obvious applications are patient tracking in the hospital, children monitoring, location finding of the product, vehicle monitoring and tracking for the logistics, etc. The accuracy of the location estimation and the reliable localization system are the main factor required. In spite of that, the relatively simple and low cost system is preferable.

In recent days, wireless network technology-based localization and tracking systemareused to locate the people or object.The well-known technology is global positioning system (GPS)-based, cellular-based, wireless local area network (WLAN standard such as IEEE802.11b), ultra wide band (UWB), Bluetooth (IEEE 802.15) and radio frequency identification (RFID). Some well reviewed localization papers can be found, e.g.[1], [2].

This paperpresentsdevelopment of user-friendly GUI for indoor localization using RFID passive tags. RFID has wide applications in the automobile assembly industry, warehouse management and the supply chain network and has been recognized as the next promising technology for positioning system. RFID tag has three typesi.e., active tag; passive tag and semi-active tag [3].In this paper, RFID passive tag is deployed.It has benefit factors such as lowcost and low power consumption. As we know, it gains energy from the electromagnetic wave transmitted by the reader.Moreover, the fingerprint-based technique is applied to find the location of the target.

Fingerprint-based technique has advantages in the accuracy of the system since it depends on the density of fingerprint nodes that deployed in the system. In this paper, the reader is employed as target and the 81 RFID passive tags as reference are scattered to the fingerprint location.The estimated location of the target node is achieved by implementing the GUI.The design for GUI supportsthe user to use the programeasily. It also can determine the location of the target by putting the location number of the target,the next step,the program will show the location of the target and the error distance clearlyin the monitor of computer.

Thispaper is organized as follows. Section II describes of the algorithm model. Experiment system and setup are presented in section III.The results and discussion are explainedin section IV. Finally, we draw conclusion in section V.

II. DESCRIPTION OF THE ALGORITHM MODEL

A. *Fingerprint Localization Technique*

Location fingerprint is a location sensing technique which involves a two-phase process. The main points of this technique are the selection of the spatial signature and the method in constructing database. The commonly used of pattern matching algorithm is shown in Fig. 1[4]. First, in the offline or training phase process, we record the data and get information from every taglocation in the experiment area. The steps of database recording are; firstly, set the location of desired fingerprints that want to be observed. For this paper, the 81 locations of fingerprint are applied. The information of the fingerprint that have relation with location of the fingerprint will be stored in the database that shown in Table I.For instance, let the number of fingerprint location as F (F_1,F_2,..., F_{81}).Secondly,recordID of all tags that has been detected by RFID reader, the group of intersected tags that detect in this step as D (D_1, D_2, ...,D_{81}). It means that D is the information of fingerprint location in all of 81 locations, F_1, F_2,..., F_{81}.

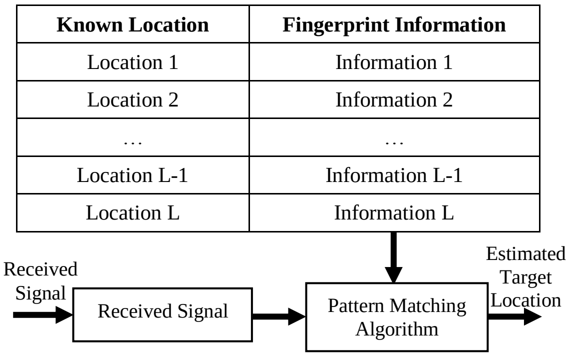

Figure 1. Location fingerprint technique

TABLE I. FINGGERPRINT DATABASE MODEL

Fingerprint Location	Fingerprint Information
F_1	D_1 ={Reference tags that detected at F_1}
F_2	D_2 ={Reference tags that detected atF_2}
…	…
F_{80}	D_{80} ={Reference tags that detected at F_{80}}
F_{81}	D_{81} ={Reference tags that detected at F_{81}}

The second phase is the online phase. Inthis phase, the estimated location is measured by comparing the current ID tag information with those that are in fingerprint database using two proposed methods that will be explained in the next section. Let call Method 1 and Method 2 for short and easy to remember.

B. Maximum Number of Intersect Tag: (Method 1)

Method 1is one of the methods that include in scene analysis techniquethat uses for estimate location of the target. This method has an idea to provide the maximum number of intersected tags from fingerprint location. The location of the fingerprint that provides the maximum number of intersected tags will be referred to the location of the target. In this paper, the numbers of observed location of the target node are 15 locations.

Giventhe number of intersection$N_1,\ N_2,\ N_3, \dots, N_{15}$, which can befound by calculatingthe group of detected tags from the observed tags $DO_1,\ DO_2, DO_3, \dots, DO_{15}$and compare with tags in fingerprint $D_1,\ D_2, D_3, \dots, D_{81}$.

$$N_i = Number\ of\ DO_i \ \cap\ D_k,(1)$$

where i= 1, 2, 3, …, 15be the location index of the 15 observed locations of the target and k = 1, 2, 3, …, 81be the location index of the 81 fingerprint locations. The maximum number of the intersected tags is investigated. Here, it has two cases;(i) one fingerprint location provides the maximum number of intersected tags, (ii) more than one fingerprintsprovide the maximum numberof intersected tags.

Case 1: The maximum number of intersected tags is provided by only one of fingerprint location. The location of the target (in this case is the reader) returnsas the location of the fingerprint [4],whichcan be shown as

$$(x_{est}\ , y_{est}) = \mathrm{LF}\ (x, y),(2)$$

where $x_{est}\ , y_{est}$ is the coordinate of the target and LF (x, y) is the coordinate of the fingerprint or we can say it is the coordinate of true location.

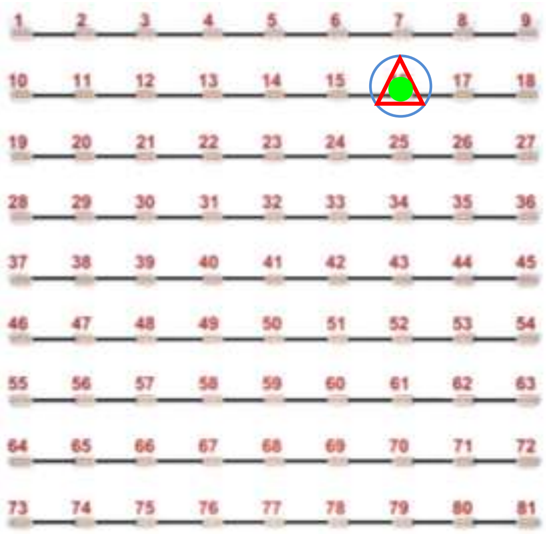

Figure 2. Illustration for case 1 of method 1

Fig. 2 shows the illustration of method 1 that the maximum number of intersected tags is provided by only one of fingerprint location. The numbered small rectangular represents as the fingerprint location which actually placed at the tag location, the red triangle represents as the observed location.After intersect between the tags detected at the red trianglewith those in the fingerprint database, we can get the maximum number of intersected tags is 11; say N_{max}= 11. The fingerprint location providing the maximum number of intersected tags that is the fingerprint location of 16 (F_{16})which represents as the blue circle. Therefore, the estimated location of the target is the location of this fingerprint and represented by the green dot. The coordinate of this location is (300, 50), as shown in Fig. 2.

Case 2: After intersection, the maximum number of intersected tags is provided by more than one fingerprint locations, so the location of the target can be calculated by the center of gravity (CG) of these fingerprint locations [4]. CG is a geometric property of any object andit is the average of two or more locations.So, for the coordinate of the target locationcan be estimated as

$$(x_{est}\ , y_{est}) = \frac{LF_{1x}+LF_{2x}+\cdots+LF_{nx}}{n}, \frac{LF_{1y}+ LF_{2y}+\cdots+ LF_{ny}}{n}, (3)$$

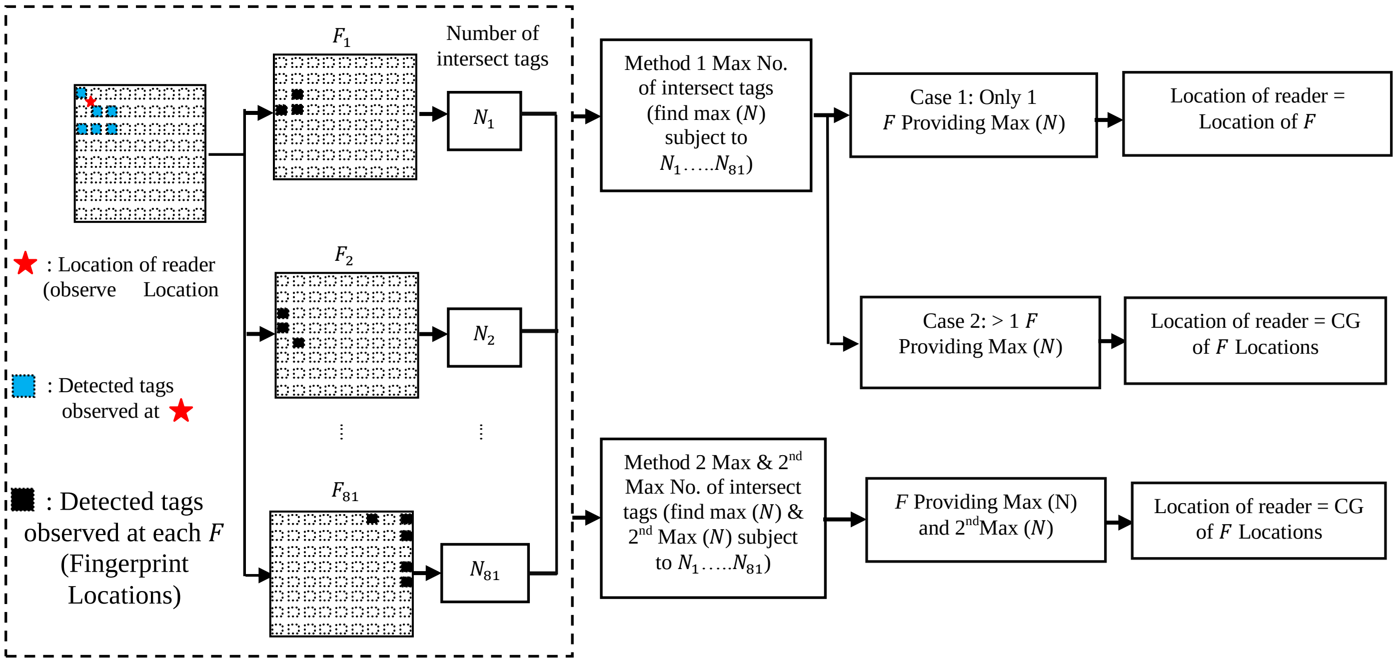

Figure 3. Summarized flowchart of two proposed location estimation methods

where $LF_{1x}, LF_{2x}, \ldots, LF_{nx}$ is the locations of the fingerprint in x axis and $LF_{1y}, LF_{2y}, \ldots, LF_{ny}$ is the locations of the fingerprint in y axis, n is the number of fingerprints that provide the maximum number. Fig. 3 shows the summarized flowchart of two proposed location estimation methods, in which Method1 already explained but Method 2 will be explained in detail in the next section.

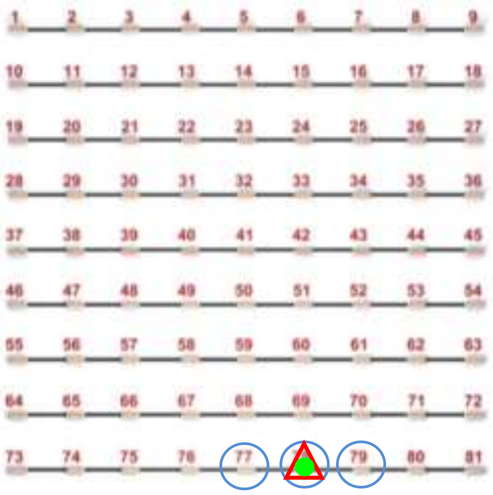

Figure 4. Illustration for case 2 of method 1

Fig. 4 shows the example of case 2, the tags of observed location are intersected with those of all fingerprint locations and it is found that the maximum number of intersected tags is 5, say N_{max} = 5. The fingerprint locations providing the maximum number of intersected tags are F_{77}, F_{78} and F_{79}, in which their locations are represented by the blue circles. The coordinate of the estimated location of the target is the CG of F_{77}, F_{78}, F_{79} locations. By calculating based on the Eq. (3), the estimated location of the target is (250, 400) which is represented at the green dot location.

C. Maximum and 2nd Maximum Number of Intersect Tag (Method 2)

This method is the extension from method in *B*, in Method 1 will observe only the maximum number of intersected tags (N_{max}). But in this method, it will get the values includingmaximum and 2nd maximum number ($N_{2^{nd}max}$). To calculate the estimated location of the target of intersected tags, the CG of fingerprint locations is used as average equation.

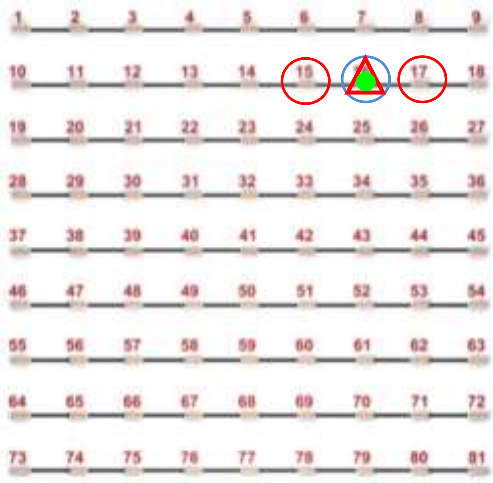

Figure 5. Coordinate of estimate location method 2

For instance, in Fig. 5, let the red triangle be the observed location, then after intersection between detected tags at the observed location and those at all fingerprint locations, it is found that the maximum number of intersected tags (N_{max}) is 11 that refers to the location of 16 (F_{16}) represented by the blue circles. The second maximum number of intersected tags ($N_{2^{nd}max}$) is 10, that the locations of 15 and 17 (F_{15}andF_{17}) and are represented by the red circles.From here, the coordinate of estimated location is the CG of fingerprint numberF_{15}, F_{16},F_{17} that it can provide the estimated location (300, 50)at the location of the green dot.

III. Measurement System and Setup

First step, we have to write ID information into the tags (81 tags) by the reader. After that, these tags will be stuckto the ceiling as shown in Fig.6. The height from the floor to the ceiling is 300 cm and the reader from the floor is 120 cm.The area of interest is 400 x 400 cm and the distance between tagsis 50 cm.

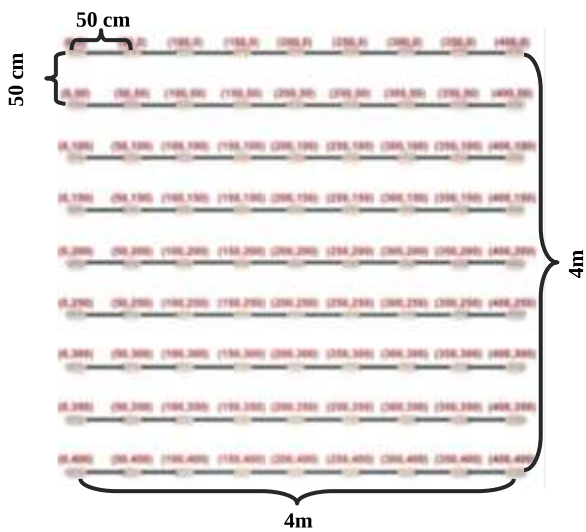

Figure 6. The model of the experiment setup in 4 m × 4m

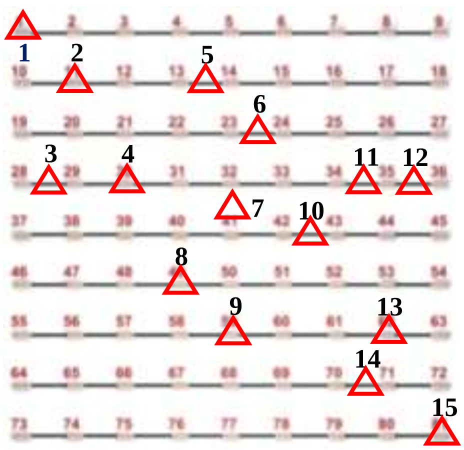

Figure 7. The 15 location of the target in the fingerprint locations

Fig. 7 shows the red triangles as the 15 locations of the observed locations. These locations can be estimated by the intersection with all of fingerprint locations using two methods that have beenpreviously explained.In this paper, we consider the location of the target in 2 cases: firstly, the observed location is at the exact location of the fingerprint location (i.e. location no. 1, 2, 4, 8, 9, 13, 15) and secondly, the location is at the middle location of two fingerprint locations (i.e. 3, 5, 6, 7, 10, 11, 12, 14).Table II shows the true coordinate of the 15 observed locations.

TABLE II.15Observed Locations

Observe Location	True Location (x, y)	Observe Location	True Location (x, y)
Location 1	(0,0)	Location 9	(200, 300)
Location 2	(50,50)	Location 10	(275, 200)
Location 3	(25,50)	Location 11	(325, 150)
Location 4	(100, 150)	Location 12	(375, 150)
Location 5	(175, 50)	Location 13	(350, 300)
Location 6	(225, 100)	Location 14	(325, 350)
Location 7	(200, 175)	Location 15	(400, 400)
Location 8	(150, 250)		

IV. ResultsAnd Discussion

A. Result of Location Estimation

In this section, we will show the example to find the location of the target node using both Method 1 and Method 2, respectively. By using Method 1, in the first case for example, the observed location number 1,F_1 (0, 0) from Table II. The group of detected tags in the fingerprint number 1, F_1, is D_1 = 1, 2, 4, 10, 19, 20and the group of detected tags in the observed location number 1 is DO_1= 1, 2, 4, 10, 20.After the intersection, N_{max} = 5 and the target location is in the same location of the fingerprint. It indicates the value of the distance error equal to 0 cm.

The second case, the estimated location at the middle location of two fingerprint locations is applied. For instance in Fig. 7, the observed location number 3 is located between fingerprint locations number F_{28}andF_{29}, and the coordinate of the observed location is (25, 150). The group of detected tags in the observed location number 3 is DO_3= 10 11 19 20 28 29 37 38and the database information in fingerprint number 28, F_{28} is D_{28} = 10 11 19 20 28 29 37 38 46 48. The database infingerprint number 29, F_{29} is D_{29} = 10 11 19 20 28 29 30 32 37 38 39. After intersection, it providesthe maximum number of intersected tags, N_{max} = 8and the location of the target is (25, 150), it means that the value of distance error is 25 cm.

By using Method 2, for example, the observed location number 8 have the group of detected tags, D_8 = 33, 48, 49, 57, 58, 59, 67. After intersection with all fingerprints, we can get the maximum number, N_{max} = 6. This number comes from fingerprint location no 49, F_{49} that have the information as D_{49} = 33, 40, 48, 49, 50, 52, 56, 58, 59, 60, 67, 77, 78. For the 2^{nd}maximum number of interested tags is $N_{2^{nd}max}$ = 4. This information is provided by the fingerprint location 48 (F_{48}) and the fingerprint location 50 (F_{50}), It provides the information of the fingerprint, D_{48} = 29, 48, 49, 56, 57, 58, 77 and D_{50} = 32, 49, 50, 51, 58, 59, 60, 61, 78. After we know the maximum and 2^{nd} maximum, the coordinate of estimated location is the CG of fingerprint number F_{48}, F_{49}, F_{50}. From here, we can get the estimated location in the same location that provides the maximum number after intersected that isF_{48}, the distance error equal to 0 cm.

B. Comparation of Methods

After conducting the experiment and estimating by Method 1 and Method 2; intersection of tags at the observe location with those at all fingerprints, by two methods, we can calculatethe maximum of the distance error. For Method 1, the distance error is reached 51.54 cm at the location number 15 and 82.70 cm at location number 15 for Method 2. These results could be the issues of propagation in indoor environment such as the light, the exit door and the wall that are located near the target location number 15. The average of the distance error for both methods is less than 21 cm. Fig. 8 depicts the graph of estimated distance error in 15 locations of the target node. The average of distance error is depicted in Fig. 9.

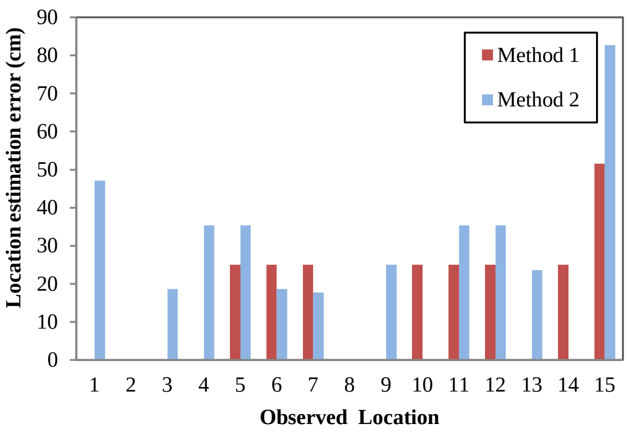

Figure 8. The comparison of distance error for two methods

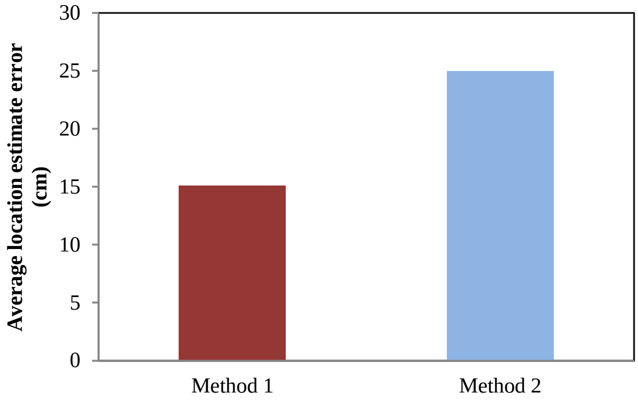

Figure 9. The averaged of the distance error for two methods

C. Implementation of GUI

In this paper, the GUI is created as the simulation tool to evaluate the effectiveness of our RFID Passive tag-based localization system. Fig. 10 shows the main menu or welcome screen of our GUI.

In order to provide the user friendly GUI, we created the GUI that has the suitable features for museum application as the example. From Fig. 10, the main focus of this GUI is to allow the user to easily simulate the positioning system in *"Positioning of Tourist"*.

Figure 10. Main menu or the welcome screen

Fig. 11 shows the menu of the positioning system which includes two methods; Maximum number of intersected tags and Maximum and 2^{nd} Maximum number of intersected tags respectively.

Figure 11. Menu of the positioning system

Fig. 12 shows the windows of both methods from the menu of positioning system. The blue circle represents as the true location of the target (known before) and the red triangle as the estimated location of the target from the system. Here we have the same design for windows form between Method 1 and Method 2.The only difference is that the title of the windows program that highlighted in the red rectangular as shown in Fig. 12.

Figure 12. Windows form of method 1 and method 2

Figure 13. Coordinate of estimate location by method 1

In the 3D animation, the self-created GUI be able to show the position of the tourist clearly. As shown in Fig. 13, the design of the room in GUI that is used to display the position of the target after we input the data to the simulation windows as in Fig. 13.

Fig. 13 shows the window of the program using Method 1and Method 2, in the observed location number 10, D_{10}, that the true location is (275, 200). After intersection, we can get the coordinate of estimated location in (250, 200) and the distance error is 25 cm for Method 1. For Method 2. The result that we get for the coordinate of estimated location is return to the fingerprint location in (275, 200), so the distance error is 0 cm.

V. CONCLUSION

This paper proposed two simple methods of the indoor location estimation using passive tag RFID. The fingerprint technique is used as the location algorithm. The concept of the intersection between detected tags and fingerprint is utilized.

Method 1 use the maximum number of intersected tags and Method 2 uses the maximum and 2nd maximum numbers of intersected tags are proposed. Because in our experiment data, Method 1 shows the better result than Method 2 since the average of estimated location error is approximately 15 cm and 25 cm for both methods. It means that, the average of estimated location error can give the distance error less than 50 cm (the distance between tags). The results of our experiment show good result and satisfy our expectation. We can conclude that our proposed methods can be applied in real situation in some applications.

For the GUI, it implements the estimated location only 15 locations by putting the location number of the target. So for the future work, we will make it automatically to estimate thetarget location. We willtry to use the other methodsand try to apply our system in 3D location.

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REFERENCES

[1] H. Lui, H. Darai, P. Ganergee, and J. Lui, "Survey of Wireless Indoor Positioning Technique and Systems," IEEE Trans. on System, Man, and Cybernetics-Part C: Apllications and Reviews, pp. 1067-1080, Vol. 37, No. 6, November 2007.

[2] A. H. Sayed, A. Tarighat, and N. Khajehnouri, "Network-based Wireless Location: Challenges faced in Developing Technique for Accurate Wireless Location Information," IEEE Signal Processing Magazine, pp.24-40, July 2005.

[3] Junru Zhou, Hongjian Zhang, Lingfei Mo, "Two-dimension Localization of Passive RFID Tags Using AOA Estimation", Instumention and Measurment Technology Conference IEEE I2MTC, July 2011.

[4] T. Jingwangsa, S. Soonjun and P. Chernthanomwong "Comparison between innovative approaches of RFID Based Localization using Fingerprint Techniques for Outdoor and Indoor Environments" ISBN 978-89-5519-146-2, pp 1511-1515, Feb. 7-10, ICACT 2010.