RFID based Localization Techniques for Indoor Environment

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***Abstract*—In this paper, the Radio Frequency Identification (RFID) technology is used for indoor localization (i.e. location estimation). The location of a RFID reader is estimated based on the known locations of the RFID tags attached to the ceiling with 60 cm separation. Two arranged pattern of tags are considered. One is a square arranged pattern and another one is a triangle arranged pattern. Then, two simple location estimation methods are employed. The basic principle of location estimation for both methods is based on the average of the locations of detected tags observed by the reader. For the first estimation method, only maximum and minimum coordinates of detected tag are average. But for the second estimation method, all coordinates of detected tag are average. The effectiveness of tag arranged pattern and the location estimation methods is evaluated by the indoor experiment data. The results of the location estimated by both methods are compared. Also, the results of location estimation using the square and triangle arranged patterns are also shown. It is illustrated that the triangle arranged patterns gives better results than the square pattern in some certain. Moreover, the location estimations error for all observed locations for both methods are less than 30 cm. Furthermore, the average of the location estimation error for both methods is less than 15 cm. This is satisfied and applicable for some indoor applications.**

***Index Terms*—localization, RFID, indoor environment**

I. Introduction

Indoor localization systems have become very popular in recent years. There are various applications mainly for security and location services. There are many methods used to estimate locations such as GPS, radio-frequency identification (RFID) and Cellular-based, etc. Among these wireless technologies, RFID technology is very popular for developers and researchers because of its advantages such as high data rate, availability in non line of-sight (NLOS) environment, high security, cost effectiveness and compactness. Many RFID based localization techniques have been presented. The example of some well-known techniques can be found in literature [1]-[3]. RFID is to identify the characteristics of each object by using radio frequency and focusing on collecting and regaining data sending from electromagnetic transmission to an RF compatible integrated circuit. The RFID consists of RFID tags and RFID readers. There are generally two types of RFID tags: active RFID tags, which contain a battery and can transmit signals autonomously, and passive RFID tags, which have no battery and require an external source to rouse signal transmission. In terms of localization, the RFID localization can be categorized into two types, i.e., reader localization, and tag localization. The example of reader localization: Lee and Lee [4] proposed localization for a mobile robot. Han et al. [5] proposed the better method than to improve the error; hence the way of setting tags in triangular pattern resulting in the reduction of the number of tags and maximum estimation error. The example of tag localization: Ni and et al. [2] proposed LANDMARC technique which employs reference tags at known locations as landmarks to the system. The location estimation accuracy depends on the placement of reference tags, especially the density of the deployed reference tags. The extensive research from the LANDMARC was proposed by Jin et al. [6] by decreasing the number of reference tags. When the reference tags are selected, the reader receives the target location by further adding the computed coordinate result with the average error range of all the reference tags providing a better accuracy than LANDMARC.

In this paper, only reader localization is concerned because of the lower system cost. The location of the reader can be estimated using the average of locations of detected tags according to two simple methods: one is the average of the locations at maximum and minimum coordinate of the detected tag and another one is the average of all detected tag locations. Moreover, two arranged pattern of tags are considered. One is a square arranged pattern and another one is a triangle arranged pattern. The effectiveness of tag arranged pattern and the location estimation methods is evaluated by the indoor experiment data. The results of location estimated by both methods are compared. Also, the results of location estimation using the square and triangle arranged patterns are also shown. The rest of the paper is organized as follows. Section 2 describes the location estimation. Section 3 explains the experiment system and setup. Section 4 shows the results and gives the discussion. Finally, Section 5 is the conclusion.

II. Location Estimation

A. Localization Estimation Methods

In order to estimate the location of the target (the reader), reference tags are arranged in fix and uniform pattern on the ceiling at known locations. The reader at each observed location can differently detect reference tags. The location of the reader can be estimated using the average of locations of detected tags according to two simple methods which are briefly explained in this section.

1) Average of maximum and minimum coordinate: In this method, the location of the reader can be estimated by calculating the average of the detected tag locations at maximum and minimum coordinate of the detected tag as

$$x_{est} = \frac{\max(x_1,...,x_n)+\min(x_1,...,x_n)}{2} \quad (1)$$

$$y_{est} = \frac{\max(y_1,...,y_n)+\min(y_1,...,y_n)}{2} \quad (2)$$

where N represents the number of detected tags by the reader and x_1, x_2, ...,x_n, y_1, y_2, ..., y_n as well as represent the coordinates of detected tags for x and y directions, respectively.

2) Average of all coordinates: In this method, the location of the reader can be estimated by calculating the average of all locations of detected tags so that this method can be called the center of gravity (C.G.) [7]. Let denotes the coordinate of the detected tags. The location of the reader can be estimated by

$$(x_{est}, y_{est}) = \left(\frac{T_{1x}+T_{2x}+...+T_{nx}}{n}, \frac{T_{1y}+T_{2y}+...+T_{ny}}{n}\right) \quad (3)$$

where $(x_{\text{est}}, y_{\text{est}})$ is the estimated location T_{1x}, T_{2x}, ... , T_{nx} are the location of detected tags in the x direction and T_{1y}, T_{2y}, ... , T_{ny} are the location of detected tags in y direction.

B. Tag Arranged Patterns

In this paper, the uniform pattern of the tag arrangement is considered. The simplest one is the square arranged pattern as shown in Fig. 1. It is the fact that when the separated distance between tags is reduced, the location estimation accuracy is improved. However, more number of tags is needed leading to increasing cost. Therefore, to deal with this issue, the triangle arranged pattern (shown in Fig. 2) is introduced to reduce the location estimation accuracy without increasing the tag number.

C. Location realization area

The realization area is defined as the circular area with radius d_i $(0 < d_i < 2d_r)$ where d_i and d_r are the distances between tags and the radius of the reader's range, respectively, as shown in Fig. 3. This means the maximum separated distance between reference tags is smaller than RFID reader's maximum realization. Therefore, it is guaranteed that at least one tag is found so that the reader can always receives the information of the tags.

III. Experiment System and Setup

A. System and environment

The RFID based localization system consists of tags, the reader and the computer with the software collecting the data received by the reader. In general, there are three types of tags: active, passive and semi-passive tags. However, the passive tags are utilized in this paper because of cost effectiveness. The passive tag with linear polarization is used. Each tag has a unique ID number. The UHF-band (902-928 MHz) RFID reader equipped with the linear polarized antenna is employed [10].

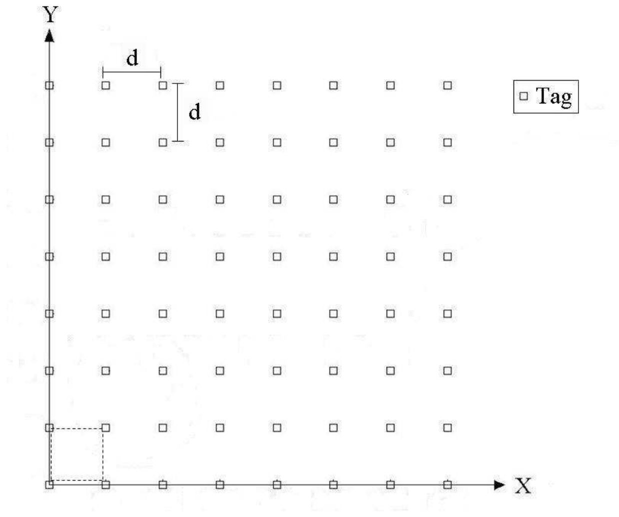

Fig. 1. Reference tags are placed in the square arranged pattern.

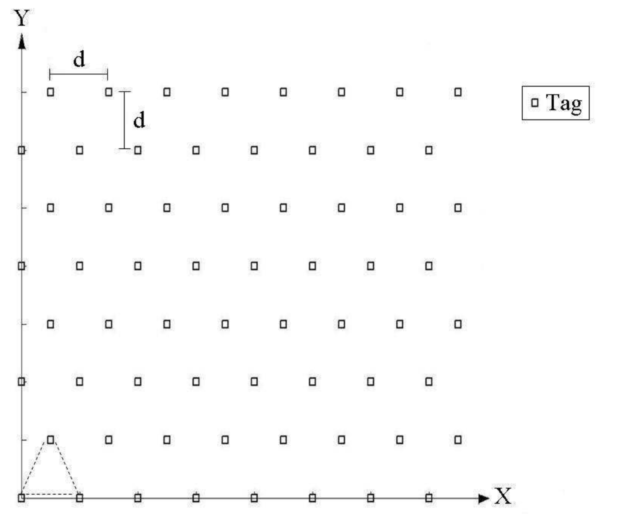

Fig. 2. Reference tags are placed in the triangle arranged pattern.

The experiments were conducted in 29 locations (one location for one measurement) in which separated distance from each observed locations is 30 cm shown in Fig. 4.

B. Experiment setup

The reference tags are placed on the ceiling where the height from the floor is 300 cm and separated distance from each reference tag is 60 cm as shown in Fig. 5. The total reference tags used are 64. The reader is placed on the camera tripod facing directly to the tags attached at the ceiling as shown in Fig. 6. The height of the reader from the floor is 180 cm. The

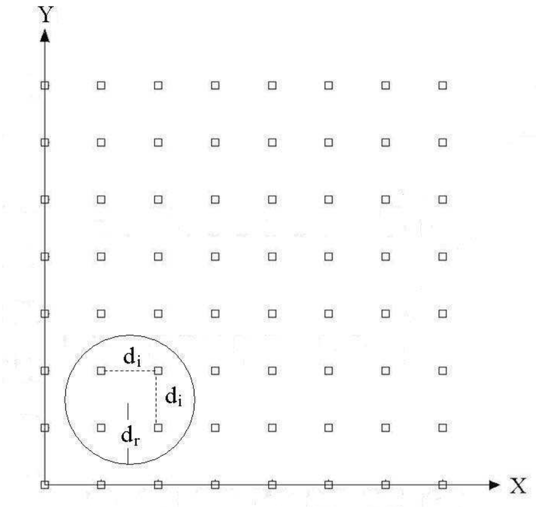

Fig. 3. The defined realization area.

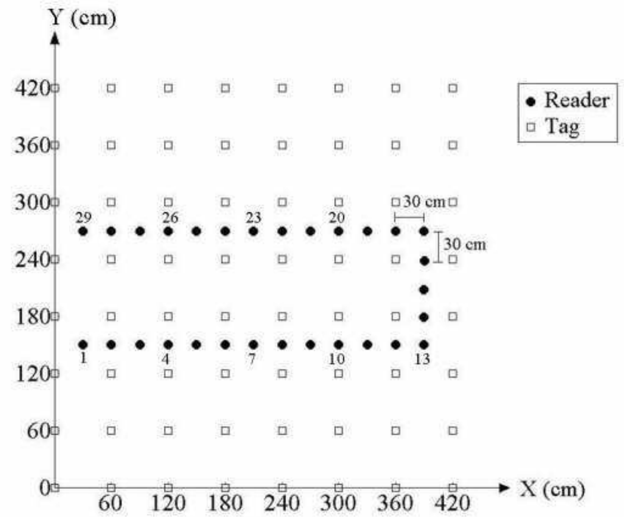

Fig. 4. The 29 observed locations with 30 cm separation each.

reader equipped with the computer installing the software and application development kit is placed on a simple carrier. Two cases of experiments were conducted, for the first experiment case, the reader is arranged in square pattern and for the second experiment case, the reader is arranged in triangle pattern.

IV. Results and Discussion

The experiments were conducted to evaluate the effectiveness of the proposed location estimation methods and to investigate the performance of the arranged patterns. The results of the estimated location error using the average of maximum and minimum coordinate technique and average of all coordinates technique are shown in Fig. 7 and Fig. 8, respectively. It is shown that the location estimations for all observed locations for both methods are less than 30 cm. Figure 9 shows the results of the average estimated location

Fig. 5. The reference tags placed on the ceiling in the square arranged pattern.

Fig. 6. The reader faces directly to the reference tags.

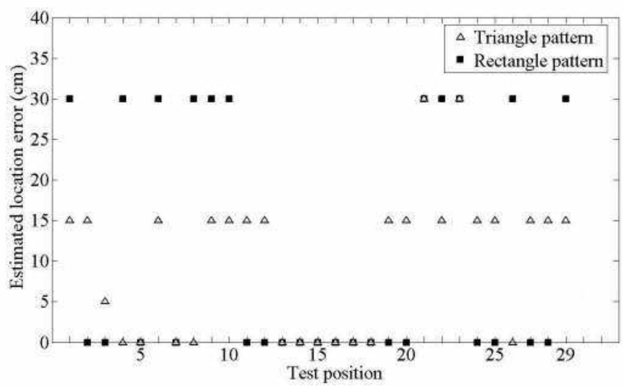

Fig. 7. Estimated location error of average of maximum and minimum coordinate technique.

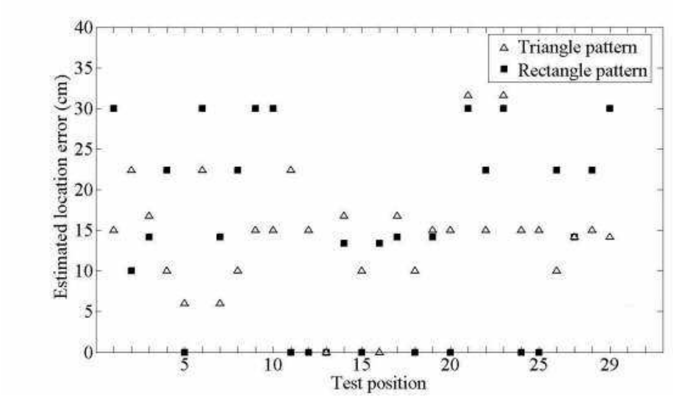

Fig. 8. Estimated location error of average of all coordinate technique.

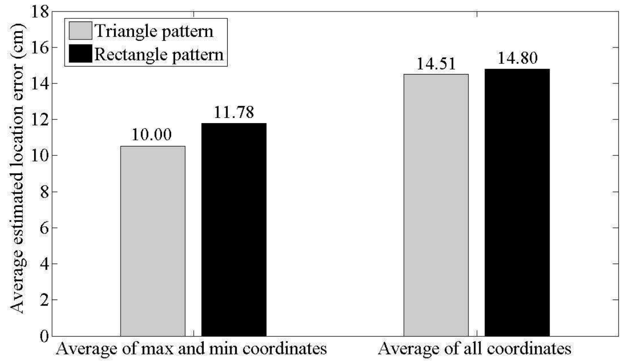

Fig. 9. Average estimated location error

estimation error for both location estimation methods and for both square and triangle arranged patterns. From Fig. 9, the average error using the average of maximum and minimum coordinate technique is smaller than that using the average of all coordinate technique. Moreover, the average error for the triangle arranged pattern is smaller than that for the square arranged pattern as expected.

V. Conclusion

This paper presents the RFID based localization for indoor environments. The location of the reader can be estimated using the average of locations of detected tags according to two simple methods: one is the average of the locations at maximum and minimum coordinate of the detected tag and another one is the average of all detected tag locations. The results of location estimation show that the former gives smaller error than the latter. Moreover, two arranged pattern of tags are considered. One is a square arranged pattern and another one is a triangle arranged pattern. It is found that the location estimation is improved using the triangle arranged pattern as expected. This shows that the accuracy of location estimation can be improved just by rearrange the tag pattern without increasing number of the tags.

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