Comparison between Innovative Approaches of RFID Based Localization Using Fingerprinting Techniques for Outdoor and Indoor Environments

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Abstract—In this paper, two novel localization algorithms using a fingerprint technique are proposed. The performance evaluation of these algorithms is compared by calculating the location estimation error. The feasibility for indoor and outdoor applications is investigated. The Radio Frequency Identification (RFID) System is utilized by the reader being the localized target. The passive tags are chosen as reference tags. The basic principle of the fingerprint technique is to find the target location by comparing its signal (or information) pattern to a beforehand recorded database of known location data. Consequently, there are two main steps for estimating the target location: the detected tags, in the first place, discovered by the reader at each fingerprint location are stored in the database and called a fingerprint. The reader location, in the second place, can be estimated by using two proposed methods. The performance of each method is verified by experiment data. The best results of location estimation error among one another for outdoor environment is less than 38 cm and for indoor environment is less than 35 cm. Furthermore, the investigation found that proposed methods can be used in the real applications for both indoor and outdoor environment.

Index Terms—Fingerprint, localization, outdoor environment, indoor environment, RFID,

I. INTRODUCTION

Radio localization has been extensively researched in present years in consequence of its significance for several wireless applications. Indoor applications are for instance, home, office, supply chain, wildlife monitoring, intelligent transport systems and so on. Outdoor applications are for instance, determining/guiding the people or object locations, navigating the car, and be used in a wide variety of markets. However, the accuracy of the location estimation and the trustworthy localization system are the main factors required. Moreover, the relatively simple and low cost system are also preferable. To deal with these requirements, a great number of localization techniques related with the recent technologies have been proposed in the literature. The well-known technologies are Global Positioning System (GPS)-based, Cellular-based, Wireless Local Area Network (WLAN), Ultrawideband (UWB) and radio frequency identification (RFID). Furthermore, there are many localization algorithms have been proposed, e.g. [1]-[2]. Amongst wireless technologies, RFID has been popular for the researchers due to its ad-vantages such as high data rate, availability in non line-of-sight (NLOS) environment, high security, cost effectiveness and compactness.

A great number of RFID based localization techniques and wide researches have been suggested and can be found in literature [1],[3]-[9]. In general, the RFID based localization can be classified main types into the tag localization e.g. [5] and reader localization e.g. [10] in which the tag and reader position is estimated, respectively. For the localization algorithms, there can be classified main categories into (i) triangulation and (ii) scene analysis (sometimes called fingerprint) [1]. In the triangulation-based localization techniques, time of arrival (TOA) and time dif-ference of arrival (TDOA) [2]-[3] or conventional angle of arrival (AOA) are measured and require multiple Base Stations (BSs) and often fail to estimate locations of mobile terminals in a dense multipath environment. Fingerprint techniques have been developed [11]-[13] to overcome these issues. This paper is organized as section II is described an overview of location fingerprint technique. In section III, the measurement organization and system are described. Section IV, Proposed location estimation Methods are presented. For section V Results and Discussion are explained. Finally, in section VI, the conclusion is given.

II. AN OVERVIEW OF LOCATION FINGERPRINT TECHNIQUES

The basic principle of the location fingerprinting algorithm is to find the location of the mobile terminal by comparing a signal pattern received by a BS with prior known signal (or information). The signal (or information) is stored in the database of known signal location information via signal pattern matching algorithms as shown in Figure 1. In this case, the database needs to be constructed in advance [14]. For this paper, the fingerprint technique is utilized since only one BS is needed and the comparatively simple equipment can be employed. In addition, the reader localization is contemplated by reason of the lower system cost comparing to the tag localization. Although, a large number. That is why the reader localization is used for this work.
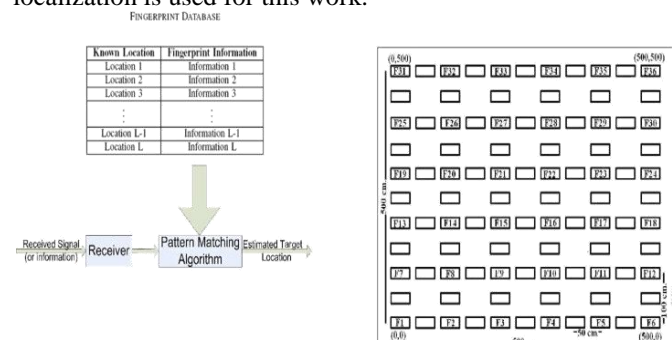

Fig. 1. Fingerprint based Localization.

Furthermore, outdoor and indoor localization techniques based on UHF band RFID is proposed. Passive tags are employed and attached on the floor and the ceiling with known location for outdoor and indoor environment, respectively. The data, firstly, will be recorded in database. After that, the reader compares the data (i.e. the detected tags) as a fingerprint in the database to estimate the location. The performance of these proposed technique are evaluated by using experiment data.

III. MEASUREMENT ORGANIZATION AND SYSTEM

To evaluate the effectiveness of the proposed localization techniques, the experiments are carried out. Additionally, as mentioned, the feasibility of using proposed algorithms for indoor and outdoor environment is also investigated in this paper. The intersection between the fingerprint and the tags detected by the reader at the location of interest are utilized to estimate the reader location. Therefore, two measurement campaigns for indoor and outdoor environment are conducted by using the same measurement system.

The measurement system consists of the UHF-band (903-928 MHz) RFID reader (as a target), a number of passive tags with linear polarization (as reference tags) and the computer storing the data received between the reader and tags.

Figure 2 demonstrates the effective outdoor and indoor areas of measurement where their size are 500 cm by 500 cm and 300 cm by 300 cm, respectively. The total number of all utilized tags is 96 where the tag with location the alphabet F_j (where $j = 1; 2; 3; ::::; 36$) represents the fingerprint location and the white one represents the location of reference tags.

In this work, indoor environment is an office room where the reader at the height of 130 cm from the ceiling is set on the camera tripod facing directly up to the tags attached to the ceiling as shown in Figure 3. On the other hand, outdoor localization is conducted at the car parking where the reader at the height of 123 cm from the floor is placed on the carrier facing directly down to the tags attached on the floor as shown in Figure 4.

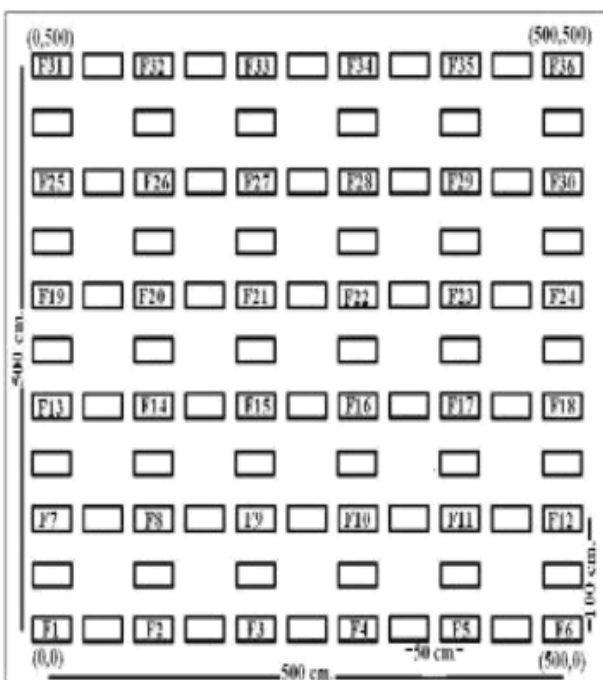## IV. PROPOSED LOCATION ESTIMATION METHODS

Fig. 2. Layout of Fingerprint Locations.

Fig. 3. Reader faces directly up to tags set on the ceiling and used as references and fingerprints for indoor environment.

Fig. 4. Reader faces directly down to tags set on the floor and used as references and fingerprints for outdoor environment.

As mentioned, the location estimation utilizing the finger-print technique is separated into two main steps. Firstly, the signal or other data gathered by the target is measured at known location after that stored in database and represented to 'Fingerprints'.
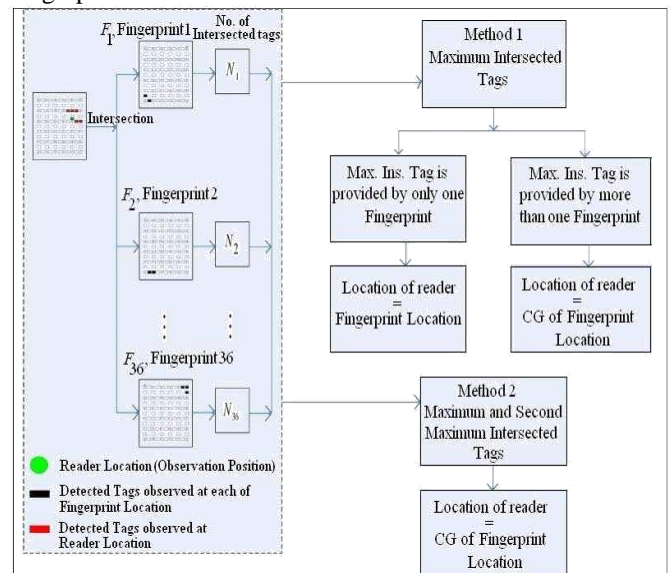
Fig. 5. Summarized flowchart of two proposed location estimation methods.

Secondly, the target location is estimated by matching its signal parameters to those in the database. The location of the data providing best match to the target data is returned as the estimated location of the target. In this section, the proposed location estimation methods based on the fingerprint technique are explained.

1) Structure of fingerprint

database created by the measure-ment follows from these steps.

Organize the measurement of the area experiment and refer to the fingerprint location as F_j (where i = 1; 2; 3; :::36 as shown in Figure 2).

Place the RFID reader at each fingerprint location and then observe the tags detected by the reader.

Store the information of detected tags observed at each fingerprint location in the database.

After finishing all measurement at all fingerprint loca- tions, the complete database is obtained and can be shown in Table I where SD_i is the set of detected tags obtained from i^{th} fingerprint location.

2) Location Estimation Two proposed location estimation techniques are described in this section: Method1 and Method 2 called for short as shown in Figure 5. The first step for these two techniques is setting the reader at the location of interest and from now on called the observed location. In the experiments, 20 and 30 observed locations are considered for indoor and outdoor localization, respectively, by represented them as the number in the white circle illustrated in Figure 6. Furthermore, the identified symbols in the indoor and outdoor location of

TABLE I
STRUCTURE OF FINGERPRINT DATABASE

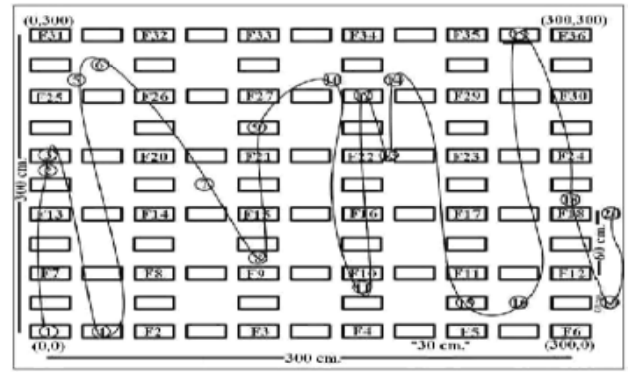| Fingerprint Position		Set of detected tags
F1	SD_1	= fReference Tags are detected at F_1 g
F_2	SD_2	= fReference Tags are detected at F_2 g
F36	SD_{36}	= fReference Tags are detected at F_{36} g

interest are P_i (where i = 1; 2; 3; ::::; N_{indoor} or $N_{outdoor}$, by = 20 and $N_{outdoor}$ = 30, respectively). Hence, the

second step is to carry out the location of the reader at each of observed locations using two proposed methods which are described from hereon.
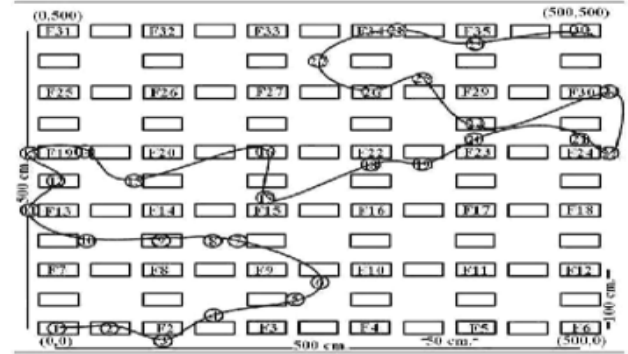
A. Method 1: Maximum Intersected Tags

The set of detected tags received from each of observed locations SP_i (where i = 1; 2; 3; ::::; n, by n = 20 or 30, for indoor and outdoor case, respectively) is intersected to the overall of sets of fingerprints, SD_j (where j = 1; 2; 3; ::::; 36, respectively). Hence, the intersection number of detected tags is obtained by each pair of intersection and referred to as N_j corresponding to the 36 pairs obtained by the comparing be- tween each of observed locations and all fingerprint locations, i.e.,

$$N_j = Number of SP_i \setminus SD_j ; \qquad (1)$$

The maximum value of N_j is examined and represented as N_{max}. Then the location estimation will be obtained by considering two cases as follows.

Fig. 6. Tags placed to the ceiling and on the ¯oor for indoor and outdoor, respectively.

Case1: If N_{max} is provided by only one fingerprint, the location of the RFID reader is defined as the location of fingerprint.

− Let F P (x; y) denote the coordinate of the fingerprint location, the location of the reader can be estimated as

$$(x_{est} ; y_{est}) = F P (x; y); \qquad (2)$$

where (x_{est} ; y_{est}) is the estimated location.

Case2: If N_{max} is provided by more than one finger-prints, the location of the reader is estimated by using the proposed location estimation techniques.

− That is if a set of detected tags at P_i has a best match to several sets of detected tags at corressponding F_j .

− The center of gravity (CG) is used to calculate the location of the reader by averaging the locations of those fingerprints, as shown below,

$$(x_{est}; y_{est}) = (\frac{F P1x + ::: + F Pnx}{N} ; \frac{F P_{1y} + ::: + F P_{ny}}{N}); (3)$$

F P_{iy} are the location of fingerprint in y direction, where n = 1; 2; 3; ::::; N , and N is the number of fingerprints providing N_{max}

B. Method 2: Maximum and Second Maximum Inter-sected Tags

This method is the extension of Method 1 while the second maximum number of intersected tags is also considered.

− CG is used to carry out the location of the reader by averaging the fingerprint locations of Method 1 with the fingerprint locations of the second maximum number of intersected tags.

The estimated location of the reader can be determined by utilizing (3) which the CG of the fingerprint locations providing both of the maximum intersected tags and the maximum and second maximum intersected tags.

V. RESULTS AND DISCUSSION

The measurement experiments in

20 and 30 locations of the reader (for indoor and outdoor, respectively) were conducted in order to evaluate the effectiveness of the proposed methods. The location estimation errors between Method 1 and Method 2 are compared as demonstrated in Figure 7. In this case, the square refers to as the estimated location using Method 1 and the diamond referes to as the estimated location using Method 2. The experiment results found that Method 2 apparently gives the better estimation (smaller error) for both of indoor and outdoor environment. Although, both methods have more error in some points than it should be; espectially, when the observed location is placed near the exit door and wall for indoor environment; or when it is placed near the boudary for outdoor environment; the results are generally satisfied. where $(x_{est} ; y_{est})$ is the estimated location of the reader and $F P_{ix}$ are the location of fingerprint in x direction and
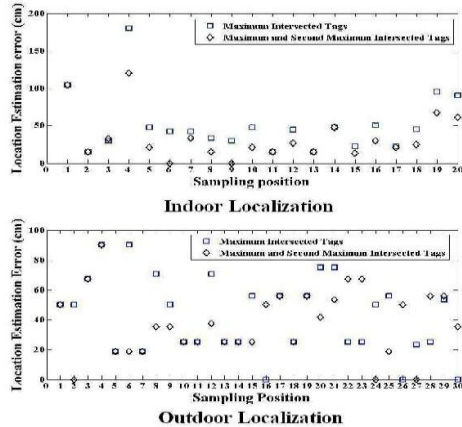

Fig. 7. Comparison of indoor and outdoor location estimation error between Method 1 and Method 2 for all observed locations,respectively.

Figure 8 shows the average estimation location error of both environments compared between Method 1 and Method 2, respectively. In this experiment found that the average location estimation is less than 50 cm and 43 cm for Method 1 in indoor and outdoor environment, respectively. While the average location estimation is less than 35 cm and 38 cm for Method 2 in indoor and outdoor localization, respectively. Moreover, when computed by Method 2 the improvement is about 32.7277 and 11.16 percent in indoor and outdoor environment, respectively.
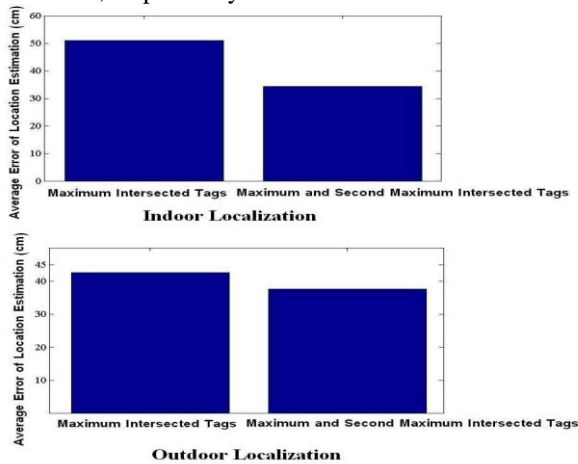

Fig. 8. The comparison of average indoor and outdoor location estimation error between Method 1 and Method 2, respectively.

It is clearly found that both of them have the same trend of location estimation error being decreased when using Method 2 which gives the better result (smaller error than Method 1). This means that the proposed methods can be used in both

environments. Conversely, the higher the improved accuracy, the harder the computing.

VI. CONCLUSION

This paper proposes two simple methods in both of indoor and outdoor location estimation utilizing RFID technology. The employed localization algorithm is the fingerprint tech-nique. The idea of the intersection between detected tags and fingerprint is used. Maximum intersected Tags is employed in Method 1 and Maximum and Second Maximum intersected Tags is employed in Method 2 for further estimating the location of the reader. Moreover, the required location es-timation error calculated by Method 2 at each observation position in indoor and outdoor is less than 38 cm and 50 cm, respectively. However, the location estimation error can be different depending on surroundings and applications for both indoor and outdoor environment. To sum up, Method 2 gives the better results for indoor and outdoor experiment. Accordingly, these proposed methods are capable of making practical use in the real applications both in the indoor and outdoor environment.

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