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Estimation of RFID Tag's Direction Based on LANDMARC Algorithm

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Abstract: The objects monitoring is a very important research and to effectively monitor objectives of interest it's necessary to be aware of the object's movement direction in a monitored area. This study presents an accurate method to determine the direction of the tagged object through a Radio Frequency Identification (RFID)-based system, using LANDMARC algorithm. A location sensing prototype system that uses (RFID) technology for locating objects. In this research method use Received Signal Strength Indicator (RSSI) technique to estimate the direction of the object. This method considers as an effective tag movement direction detection in which an original tag communication system is used as much as possible without using optional equipment, also, this algorithm able to reduces the number of antennas used to estimate the direction of the object to a lower's number as possible. The simulation results prove the accuracy of this method with a low complexity.

Key words: Radio Frequency Identification (RFID), LANDMARC, Received Signal Strength Indicator (RSSI), localization, Wireless Sensor Network (WSN), methods

INTRODUCTION

As one of the key techniques of an Internet of Things (IoT), Radio Frequency Identification (RFID) has received much attention and been widely deployed in recent years. Due to their low cost and long distance reading, RFID-based systems, especially the Ultra High Frequency (UHF) ones are desired to be introduced in access control systems. Using an RFID-based access control system, customers can be aware of the movement direction for the purpose of recognition in warehousing or shipment for inventory management or real-time traffic congestion detection and management or monitor important files or information carriers for conference management. Moreover, one can check for undesirable objects or prevent theft (Huang *et al*., 2016).

Estimation of RFID tags direction is a hot subject in Wireless Sensor Networks (WSNs). In some direction sensitive applications, node direction is essential to the whole network. To estimate the direction of the movement of the nodes in (WSNs) we can benefit from the algorithms of localization and use them to effectively Generally, localization algorithms in WSNs can be classified into two categories: range-free localization and range-based localization as shown in Fig. 1.

Compared to range-free localization, range-based localization provides higher precision. There are many range-based localization techniques such as those based on Time Difference of Arrival (TDOA) (Velasco *et al*., 2016), Time of Arrival (TOA) (Jamalabdollahi and Zekavat, 2017), Angle of Arrival (AOA) (Zhang *et al*., 2016) and Received Signal Strength Indicator (RSSI) (Li, 2006), RSSI-based algorithms have the following characteristics: low power consumption, simple hardware and high sensitivity to the environment. RSSI value

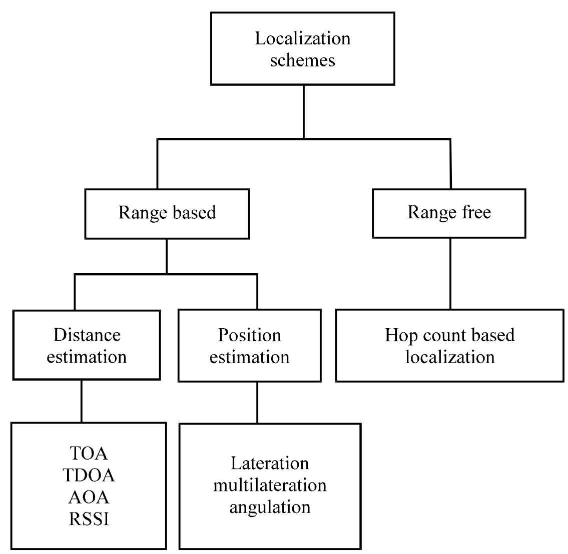

Fig. 1: Localization schemes

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heavily depends on the propagation channel. multipath propagation, Signal reflection, signal scattering noise and have great influence on the received RSSI. Therefore in practical applications, building an accurate relationship between the distance and the value of received RSSI is crucial to the performance of localization algorithms (Du *et al*., 2017).

Literature review: Saab and Msheik (2016) they proposed a Radio Frequency Identification (RFID)-based methodology that can estimate the position and orientation of an object. Unlike other RFID-based localization systems, the proposed method employs a single non steered stationary antenna and three passive tags mounted on each object. Their scheme is based on power map matching algorithm that is capable of estimating the location and orientation of objects. Unlike traditional power map matching schemes which generate the map from actual measurements, the proposed power map is automatically generated based on a simple mathematical model. The application under consideration is based on two-Dimensional (2-D) open spatial environment where the area of each object is no less than a quarter of a square meter with location estimation errors ranging to tens of centimeters.

Al-Naima and Al-Any (2011) designed a system called Vehicle Location System (VLS) based on Radio Frequency Identification (RFID). The designed system consists of passive RFID tags on vehicles, RFID readers, wireless Ethernet communication with a Central Computer System (CCS) and commanding software. In this system used two RFID reader in each intersection and each reader composed four antenna. To determine the direction of each vehicle they installed an antenna on of each side of a road, one this two antenna to identify vehicles entering the intersection and the other to identify vehicles emerging from the intersection. Compared with our proposed method, we used only one antenna to see the direction of the vehicle’s movement.

Huang *et al*. (2016) a method of accurately determining the tagged object’s moving direction in an RFID-based access control system is proposed. This method takes advantages of the backscatter phase and its trend as the tag moves. By differential operations of every two adjacent phase values, we transform the periodic phase into values whose signs in-cate the tagged object’s movement. To be more accurate, the sliding time window mechanism which can reduce the errors caused by noise and inherent cycle ambiguity of the phase is introduced.

Some of the efficient techniques to estimate the movement direction are proposed by Oikawa (2009, 2012), Wilson *et al*. (2007). Oikawa (2009) used detected time difference of the tag by the two antennas as an attribute of direction estimation in which the read time is in three formats: the first inventory time; the time when detected values exceed a threshold; the time-weighted by the read count or received power.

Oikawa (2012) proposed a method for correctly estimating the direction of tag moving in an RFID gate system is proposed. This proposed method utilizes the difference in time between the two antennas of the used reader. This method has the advantage of being ready to judge tag direction individually even when there are some tags moving in the reverse direction. Especially, when it uses the proposed algorithm of the least squares method, the precision of the estimation can be increased.

Wilson *et al*. (2007) researchers proposed a method which matches tag count percentage patterns under different signal attenuation levels to a database of tag count percentages, attenuations and distances. All of these above are the Received Signal Strength Indicator (RSSI)-based methods which are susceptible to the propagation environment and sensitive to noise and multipath effect (DiGiampaolo and Martinelli, 2014).

Hightower *et al*. (2001) the researchers proposed a well-known position sensing system which use the RFID technology called Spoton. Spoton utilizes an aggregation algorithm for three-dimensional position sensing based on radio signal strength analysis. Spoton researchers have designed and built hardware that will serve as object location tags. In the Spoton way, objects are located by homogenous sensor nodes without Existence any central control. Spoton tags use RSS information as a sensor measurement for estimating distances between tags. However, a complete system has not been made available as of yet.

Priciples of RFID: Radio Frequency Identification (RFID) is a wireless technology that uses electromagnetic waves (Radio) to transport data for automatic identification and object tracking and facilitating identification of any product or item without the requirement of any line of sight between transponder and reader.

An RFID system is composed of three basic components: a tag, a reader and a host computer (Hunt *et al*., 2007) as shown in Fig. 2.

RFID tags: An RFID tag (also referred to as a “transponder, smart tag, smart label or radio barcode”) has a unique Identification number (ID) and memory that

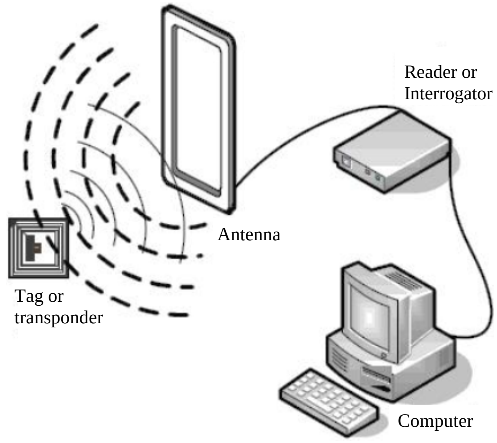

Fig. 2: Overview of RFID system

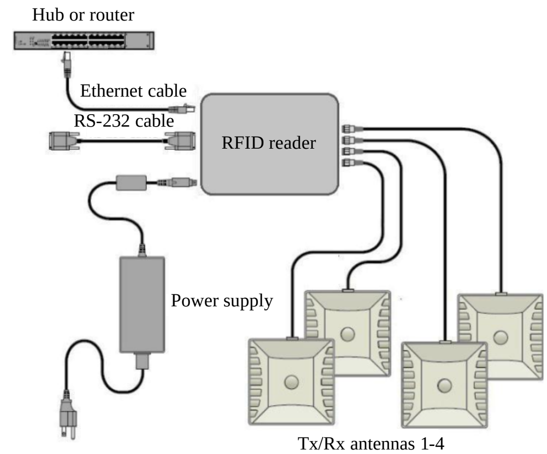

Fig. 3: RFID reader

is designed to store certain unique information (such as "manufacturer name, product type and environmental factors including temperature, humidity, etc.") (Zhang *et al.*, 2010). RFID tags include tiny semiconductor chips and miniaturized antennas inside some form of packaging. They can be uniquely identified by the reader/host pair and when applied or attached to an object or a person that object or person can be tracked and identified wirelessly (Hunt *et al.*, 2007). There are many different types of RFID tags and it is important to choose the right type of RFID tags for a particular application. According to the energizing power system, the tags can be classified into three types tags: active, passive and semi passive.

RFID readers: Reader (also referred to as a "Interrogator") as a scanning device, identifies the tags that attached to or embedded in the selected items. It varies in weight, size and may be fixed or mobile. The reader communicates with the tag through the reader antenna as shown in Fig. 3 which broadcasting radio waves and receiving the tags answer signals within its reading area. After detecting the signals from tags by the reader, the reader decodes them and passes the information to middleware (Ouyang, 2009).

RFID hosts: RFID hosts are the "brains" of an RFID system and most often take the form of a PC or a workstation. Following this analogy, the readers would constitute the nervous system while the tags are the objects to be sensed. Most RFID networks are comprised of many tags and many readers. The readers and consequently the tags are networked together by means of the central host. The information collected from the tags in an RFID system is processed by the host. The host is also responsible for shuttling data between the RFID network and larger enterprise IT systems where supply chain management or asset management databases may be operating.

Localization of wireless sensor network: One of the most important fundamental requisites that need to be resolved efficiently in Wireless Sensor Networks (WSNs) is localization in as it plays a significant performance in many applications namely environmental monitoring, routing and target tracking which is all location dependent. The main idea of localization is that some deployed nodes with known coordinates termed as anchor nodes transmit beacons with their coordinates in order to help the other nodes in the sensing field to localize themselves (Sivakumar, 2017). In general, the main localization algorithms are classified into two categories: range-free and range-based. The localization systems can be divided into three distinct components (Boukerche, 2008).

Distance/angle estimation: This component is responsible for estimating information of distances and/or angles between two nodes. Such information will be used by the other components of the localization system.

Location computation: This component is responsible for computing a node's location based on the available information of distances/angles and location of the reference nodes.

Localization algorithm: This is the main component of a localization system. It determines how the available information will be manipulated in order to allow most or all the nodes of the WSN to estimate their positions.

In RFID field, there is the simplest way for positioning which only depends on the tags detecting by readers without a distance measurement. In this case, there must be a large number of tags, so that, the reader can roughly know the position because it knows which tag (or which tags) it can read. However, people prefer some more accurate positioning methods in practice. The current scheme of RFID accurate positioning can be classified into four categories which are TOA, RSSI, TDoA and AoA (Zhang *et al*., 2016).

MATERIALS AND METHODS

To determine the tags movement direction effectively, first we are must find the location of RFID tag using one of the algorithms of localization and then measure the distance between tag and reader. To find the location of the tag we use the LANDMARC algorithm and uses the RSS distance model to measure the distance between tag and reader.

LANDMARC localization algorithm (Ni *et al*., 2004): LANDMARC is one of the many algorithms used for estimation the physical coordinates of the object's location. The current LANDMARC (Location Identification Based on Dynamic Active RFID Calibration) algorithm uses active RFID tag and takes much time in the scanning of the received signal strength. In any RF system, antenna design determines the shape of the field or propagation wave delivered, so that, range will also be influenced by the angle subtended between the tag and antenna. In space free of any obstructions or absorption mechanisms, the strength of the field reduces in inverse proportion to the square of the distance. The RFID reader has 8 different power levels. Based on the signal strength received by the RFID reader, the reader will report or ignore the received ID where power level 1 has the shortest range and level 8 has the longest range. Each reader has a pre-determined power level. LANDMARC uses having extra fixed location reference tags to help location calibration. These reference tags serve as reference points in the system, like landmarks in our daily life. The LANDMARC approach has 3 major advantages: No need of expensive readers; Environmental dynamic can be easily accommodated; Location information is more reliable and more accurate. LANDMARC, however, requires RSS value from each tag to readers (Ni *et al*., 2004).

In the experimental setup, we assume n readers, m reference tags and u tracking tags. The signal strength vector for tracking/moving tags is defined as:

$$P = (P_1, P_2, ..., P_n)$$

where, P_i denotes the signal strength of the tracking tag perceived on reader i where $i \in (1, n)$. For the reference tags, we denote the corresponding signal strength vector as:

$$Q = (Q_1, Q_2, ..., Q_n)$$

where, Q_i denotes the signal strength. We introduce the euclidian distance in signal strengths. For each individual tracking tag h where $h \in (1, u)$, we define:

$$G_j = \sqrt{\sum_{i=1}^{n} (Q_i - P_i)^2} \quad (1)$$

where, $j \in (1, m)$ as the euclidian distance in signal strength between a tracking tag and a reference tag.

Let, denotes the location relationship between the reference tags and the tracking tag, i.e., the nearer reference tag to the tracking tag is supposed to have a smaller G value. When there are m reference tags, a tracking tag has its G vector as $G = (G_1, G_2, ..., G_m)$.

k-nearest neighbor algorithm is used then to determine the number of reference tags in a reference cell that are to be used in obtaining the most accurate approximate coordinate for each unknown tracking tag. k-nearest neighbor algorithm is used with k-nearest reference tags coordinates to locate one unknown tag. The unknown tracking tag coordinate (x, y) is obtained by:

$$(x, y) = \sum_{i=1}^{k} w_i (x_i, y_i) \quad (2)$$

where, w_i is the weighting factor to the i-th neighboring reference tag. Hence, the estimation error induced will be computed with the actual coordinates of tracking tag (x_0, y_0) using:

$$e = \sqrt{(x - x_0)^2 + (y - y_0)^2} \quad (3)$$

This e will serve as our performance metric. The choice of these weighting factors is another design parameter. Giving all k nearest neighbors with the same weight (i.e., $w_i = 1/k$) would make a lot of errors. Thus, the third issue is to determine the weights assigned to different neighbors. Intuitively, should depend on the G value of each reference tag in the cell, i.e., w_i is a function of the G values of k-nearest neighbors. Empirically in LANDMARC, weight is given by:

$$w_j = \frac{1/G_i^2}{\sum_{i=1}^{k} (1/G_i^2)} \quad (4)$$

This means the reference tag with the smallest G value has the largest weight.

RSS-distance Model: This proposed method uses Received Signal Strength Indicator (RSSI) to measure the distance between the reader and the location of all tags in the RFID environment. To measure the distance between a transmitter (i.e., active RFID tag) and a receiver (i.e., reader) through the RSSI, we need to model the path loss which describes the relationship between the distance and the signal attenuation. Researchers have derived a significant relation between RSSI and distance both for outdoor and indoor measurement (Aydin *et al*., 2007).

Outdoor area measurements (Aydin *et al.*, 2007): Through Frii's formula, the relation between the distance and signal strength is deduced for the measurements of the outdoor area. Accordingly, RSS is expressed as follows:

$$P_r = P_t - P_L(d) + G_r + G_t \quad (5)$$

Where:

P_r = The received signal power (dB)
P_t = The transmitted signal power (dB)
$P_L(d)$ = The Path Loss (dB)
G_r = The transmitting antenna gain
$P_L(d)$ = Expressed as follows for free-space

$$P_L(d) = 10\log\left(\frac{\lambda}{4\pi d}\right)2 \quad (6)$$

Where:

λ = The wavelenght
d = Used for distance between the receiver and the transmitter

$$\lambda = C/f$$

Where:

λ = Wavelenght in meters
c = Speed if light (299, 792, 458 m/sec)
f = Frequency

Indoor area measurements (Aydin *et al.*, 2007): For indoor environments, log-distance path loss model, among different path-loss models in its simplest form often used for EM signals can be expressed as:

$$P_L(dB) = P_L(d_0) + 10n\log\left(\frac{d}{d_0}\right) \quad (7)$$

n is the path loss exponent depending on the building and surrounding medium which indicates the rate of path loss with the increasing distance is the reference distance and is the distance between the transmitter and the receiver. From Eq. 5-7, estimate distance d can be measured by the following equation:

$$d = P_t - P_r/10n \quad (8)$$

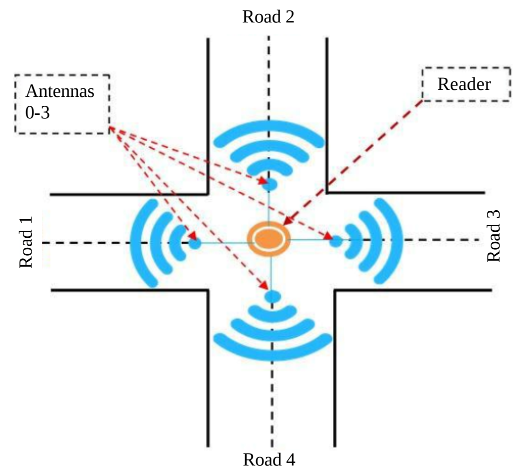

Fig. 4: Architecture of traffic intersection

RESULTS AND DISCUSSION

Performed a series of experimental simulation in MATLAB to evaluate the performance and efficiency of the proposed method for estimation of RFID tag's direction based on LANDMARC and suggest to applied this work in monitoring and reducing traffic jam system.

The first step in this simulation supposed attaches active RFID tag to all cars that can be identified by RFID readers which are placed at intersections. This system is composed of installing of one RFID reader in each traffic intersection as shown in Fig. 4. The four streets of the traffic intersection are North, East, South and West were represented as Road 1-4, respectively. In each road, only one antenna installed in the midpoint of the road near the traffic intersection between the two side of each road can simultaneously scan all the cars in the two opposite directions and this antenna can record relevant information for each car.

According to the received signal strength of the same tag ID, the direction of car's movement will be known If they enter or exit.

In the standard setup, we place one RF readers (n = 1) in our lab and 16 reference tags (m = 18) which the localization information will be used by an unknown node to estimate its location. While the other tags as objects being tracked as illustrated in Fig. 5, that refers The layout of simulation area by using 16 reference tags and one reader.

In this technique, the location of the RFID reader is known and the location of the reference nodes are also known. That means is possible to calculate the distance between each reference node and the reader using Euclidean distance equation then we can measure the

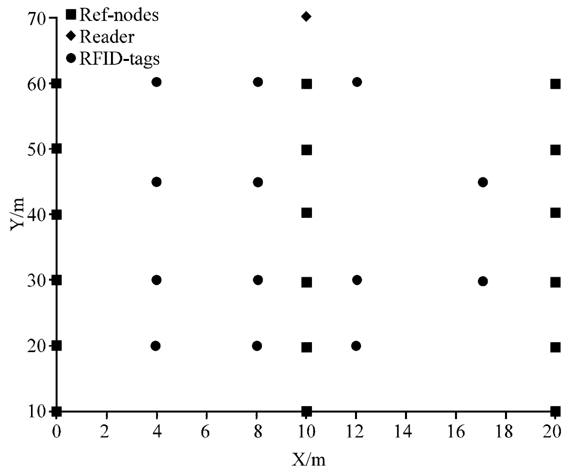

Fig. 5: Placement of RFID reader and reference tags

Table 1: The simulation result of direction estimation by using 18 reference tag and one reader

RSS between RFID tag and reader	RFID tag location	Distance between RFID tag and reader (m)	Direction estimation
-70.0330	(1, 1)	8.5820	
-68.0576	(1.25, 2.5)	8.8066	Toward reader
-64.0005	(2, 4.7)	5.2140	Toward reader
-59.1926	(2.8, 6.4)	3.2851	Toward reader
-51.0660	(3, 8)	1.4998	Toward reader

Table 2: The simulation result of direction estimation by using 18 reference tag and one reader

RSS between RFID tag and reader	RFID tag location	Distance between RFID tag and reader (m)	Direction estimation
-46.6887	(3, 8.5)	0.1046	
-59.5161	(3.7, 6.3)	2.3689	Away from the reader
-65.6322	(3.1, 3.9)	6.2022	Away from the reader
-68.6165	(2, 2)	6.9660	Away from the reader
-68.8622	(1.3, 1.9)	8.8983	Away from the reader

value of RSS by using the distance through the Eq. 5 RSS between each tracking tag and RFID reader is measured. After that using the Eq. 1 be measured the Euclidian distance in signal strengths between each reference n node and tracking node. Finally, the unknown tracking tag coordinate (x, y) is obtained by using Eq. 2.

After we have identified the location of the tracking tag, we calculate the Euclidian distance between tracking tag and the reader, compare it with the previous measurements. As shown in Table 1 if the value of the distance decreased compared with the previous distance this indicates that the RFID tag is moving toward reader or as shown in Table 2. If the value of the distance increased compared with the previous distance this indicates that the RFID tag is moving away from the reader. As shown in Fig. 6 which is a flow diagram illustrating determine the direction of tag movement depending our proposed method and also as shown in Algorithm 1.

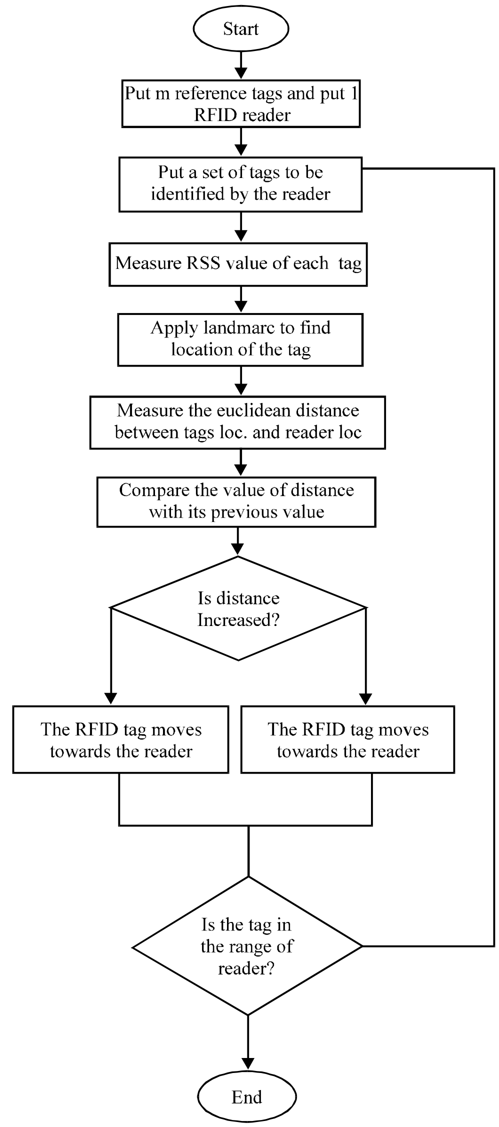

Fig. 6: Flow diagram illustrating determine the direction of tag movement depending on RSSI technique

Algorithm 1; Pseudo code of the direction movement estimation:

Input: Value of RSSI (between RFID reader and RFID tag)
Output: Movement direction and location of RFID tag
1: Do
2: Put m reference tags and put 1 RFID reader
3: Put a set of tags to be identified by the reader
4: Measure the RSS of the tracking tag perceived on the reader
5: Measure the RSS of the reference node perceived on the reader
6: Calculate (E) relationship between the reference tags and tracking tag
7: Measure coordinates of the unknown tag using LANDMARC equations
8: Measure euclidian distance between RF reader and RFID tag
9: Compare the value of distance with its previous value
10: If distance Increased then the RFID tag moves away from the reader, else the RFID tag moves towards the reader
11: If the tag in the area range of reader then go to 2, else ko to 13
12: End

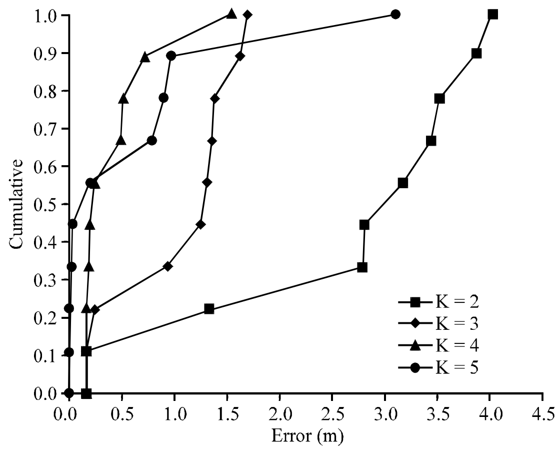

Fig. 7: Cumulative percentile of error distance for K from 2-5

Effect of the number of nearest neighbors: One of the main and important issues is to find a best K value in the algorithm. We choose different K values as K = 1-5 and compute the coordinates of the tracking tags (RFID tags), respectively and compute the mean square error between the real coordinates and the estimation coordinates of tracking RFID tag. Figure 7 as a shows the results of using different k values in the formula.

As shown in Fig. 7, K = 4 works the best and the location accuracy does not improve as the K value further increases. Keeping the same placement, we repeat the process for other locations of tracking tags. Though the positioning error distribution changes, K = 4 still gives the best location information. In fact, in all the later simulation except on a few occasions that K = 3 and K = 5 worked better in most cases K = 4 is the best choice, hence, we set 4 as the value of K in our formula in the following simulation.

Effect of the number of readers: One of the problems of using RF to locate objects is the inconsistency of the signal strength reception. This can primarily be due to the environment and the device itself.

In most cases, the environmental factors always have the most impact on the accuracy and maximum detectable range. These include issues like furniture placement, people's movement and so on. Besides, Non-Line of Sight (NLOS) is another source of reducing the location sensing accuracy. Even NLOS does not prohibit RF transmission as that of infrared, it does create the multi-path problem, meaning the signal can possibly take different paths to reach the receiver and result in interference among the received signals. To better deal with the problem, we can use more RF readers to improve the accuracy.

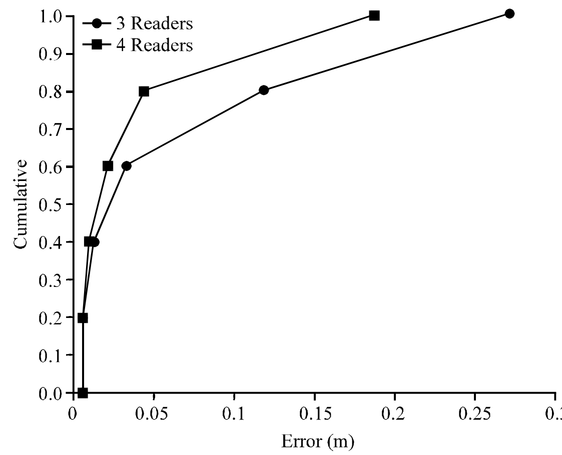

Fig. 8: Cumulative percentile of error distance for 3 and 4 RF readers

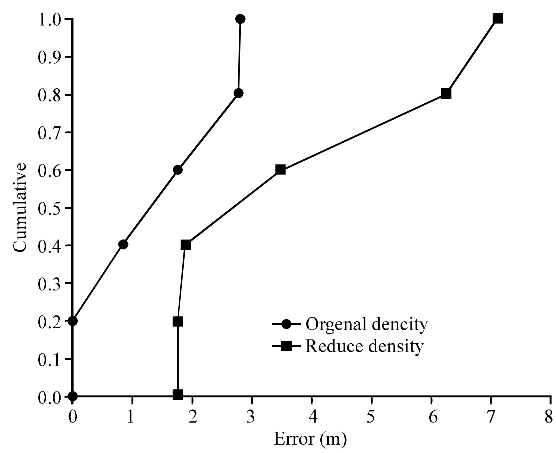

Fig. 9: Cumulative percentile of error distance with a lower reference tag density

With more RF readers, a better decision can be made for location sensing because more data can be gathered by having extra readers to do the sensing as shown in Fig. 8.

However, the RF readers are usually quite expensive, so, placing more readers means extra costs for the whole system. Due to budget constraints, we have only four RF readers. Adding more readers may not necessarily significantly increase the accuracy. It does increase the processing overhead.

Effect of number of reference tags: Intuitively, placement of reference tags should have an effect on the measurement accuracy. We can prove this in our next simulation. In our next simulation, we place the reference tags with a lower density and original density as shown in Fig. 9.

It can be seen that the accuracy of the LANDMARC system is decreased with a lower reference tag density, therefore, the accuracy of the LANDMARC system is improving with a higher reference tag density.

CONCLUSION

In this study, simulation results show that adopting active RFID tag is a viable cost-effective candidate for a method for estimating the tag's movement direction in an RFID environment was proposed. This method uses RSSI based approach for estimation the RFID tags movement direction. Our method has the advantage of being able to judge tag direction efficiently and under different environments individually even when there are some tags moving in the reverse direction.

RECOMMENDATIONS

This research was applied in simulation experiments for design a system has the ability to solve a problem of monitoring and reduce cars traffic jam. The proposed method succeeded and efficiently in achieving its objectives. In addition to that, this method was able reduces the number of antennas used to estimate the direction of the object to a lower's number as possible. Finally, the feasibility of the method was proved by simulation.

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