Plan and execution of a concurrent entity position scheme Based on reflexive RFID Tags

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***Abstract*— we examine how to glowing exploit radio frequency identification technique for concurrent locality systems (CTLS). A new organize technique, position tracking tag during reader influence control and candidate region junction, has been planned to develop the CTLS judgment exactness by eliminating trivial tag information from the estimation process. Multireaders were deployed and operate with multipower level to progressively refine the target tag region for exact position judgment. To improve the position tracking tag during readers influence control and candidate region junction, visual tag interpolation algorithms were adopted to additional refine the tag lattice to enhance position judgment. Experiments showed that the judgment errors is 70% less important than its matching part of LANDMARC and Spot ON which install regularly spaced situation tags to conclude signal potency. For spontaneous displaying the outcome, a video observation module was integrated with the CTLS to visually render the positioned objects, based on which context-aware air force can be developed. One model is a elegant wheelchair (SWC) with a gracious user-environment manage boundary that enables SWC users to cooperate with his living environment like a normal well human being.**

***Index Terms*— radio frequency Identification (RFID), concurrent entity position scheme, tag interference, multi-power level RFID reader, visual rendering.**

I. INTRODUCTION

FOR increasing human-oriented smart wheel-chairs (SWC), the goal has been in humanizing flexible automatic controllability for dissimilar users, away from which we designed to recover its human-environment communication (HEC) skill. For one SWC organized with a computer-assisted graphical user interface (GUI), integrating computer hallucination techniques, RFID identification and pan-tilt-zoom (PTZ) camera manage, enables users to act together with living environment like a normal people [1]. As shown in Fig. 1, the SWC-GUI helps users to act together with the livelihood environment with the residential functions, including seeking, locating and spotting substance in a free space, tele-health care, weak vision assistance, remote switch control and user profile organization.For locating entity locations, it has to setup a illustration observation system which PTZ

Fig. 1. The smart wheelchair system enabling the customer to work together with the environments. Controls

cameras to render the entity and space position in sequence. To find an entity in a free space, a RFID-based concurrent position scheme is developed to guess it space position and then regulate the PTZ camera to mark the surrounding space of the entity for visual representation. This entity position and spotting system be able to implemented price efficiently as compared to the one with dynamic RFID tags, e.g., ZigBee, in that reflexive tags are economical and can be particularly deployed devoid of uncontrollable power. For SWC users, the distance to the desired entity is then just a click of base gone with auto-SWC direction-finding toward the entity location.

A RTLS characteristically refers to a position of sensors cooperating with each other to identify and locate tracking objects (including people) in concurrent. It has been extensively applied in automatic benefit position and account system, fast inventory auditing and organization, and extremely noticeable specific substance in trade centers and pharmaceutical [2]. accessible applications utilize the RTLS to track lawful objects tagged in proceed [3].

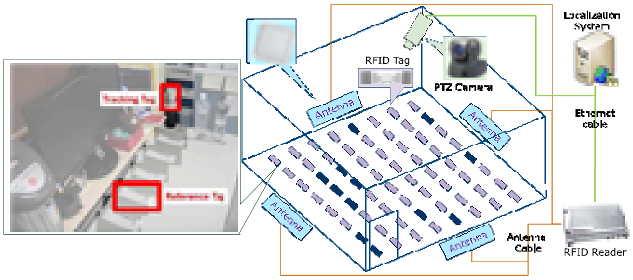

Fig. 2. A elegant space comprises PTZ camera and RFID-based RTLS.

In our job, a RTLS refers to the implement of RF signals for locating and tracking tagged entity in concurrent. The method comprises PTZ cameras and the RFID-based concurrent position element, as shown in Fig. 2. The RTLS can make possible to inspect most required substance friendly with tags, e.g. RFID tags. The RF signal returned from a tag would be conservative by more than one reader in a sensory organization [7]. We planned to LOCate TRacking tag during readers power control and hopeful locality junction, truncated as LOCTREC, which can quickly and exactly guess entity position. To accurately position a target entity, it is necessary to setup several RFID readers and organize many reference tags with expected intervals. In addition, the power of RFID-readers can be accustomed such that the signal reporting regions can be modified to eliminate redundant position tags for accurate evaluation. The RFID reader collects receptive signals from tags to guess the position of target stuff attached with tracking tags. Performing position task with multiple situation points (e.g. RFID tags) requires that distances between position points in the sensory complex be known in progress to precisely locate a tag. As compared to earlier position evaluation approaches, the number of tags that are resolute to be near the object tag would be largely concentrated and the evaluation accuracy can be enhanced.

The relax of this paper is prepared as follows: In section II, earlier works on space entity position are reviewed. Challenges and manipulations of RFID-based entity position organization are described in Section III. Section IV describes the planned position identification method, LOCTREC, and experimental outcome, from which how to utilizing the illustration observation organization to provide the position in sequence are also described. Section V presents the entity position presentation of the future method and comparisons with other RTLS methods. Section VI concludes this treatise.

II. OBJECT LOCATION IDENTIFICATION APPROACHES

entity position systems can be accepted out based on GPS, cellular phone tracking system, Wi-Fi positioning organization and RFID location Technologies. The GPS is there for outside positioning and is firm to be utilized for inside positioning in that investigation effect will reduce or remove the passion of satellite signals. Several researches have been conducted in crafty wireless position algorithms for inside positioning systems, such as the wireless sensor network (WSN) [8], wireless local region network (WLAN) [9], and radio occurrence identification (RFID) [10]. inside positioning systems based on accessible network infrastructures can give position accuracy from 1 to 10 m, but requiring high complex deployments. Under a fixed setup for inside positioning, the coverage of area is inversely proportional to their judgment exactness. The RFID technology provides a concurrent and low-cost solution for positioning systems, which utilizes radio signals to remotely categorize, track, sort and detect target stuff. Several methods have been future in trade with locating RFID tags [11]. Received Signal Strength Indicator (RSSI), Time Of Arrival (TOA), Time Difference Of Arrival (TDOA), or Received Signal Phrase (RSP) are responsive tag signals for positioning. An inverse Synthetic Aperture Radar (SAR) move toward was proposed to position moving UHF RFID tags [12].

In general, the Received Signal Strength (RSS) from a source will be attenuated in relative to communication distance. This path loss attribute is exploited to specify the relationship between signal length and transmission distance. The *Friis* equation under a free space is given by

$$P_r(d) = P_t G_t G_r \left(\frac{\lambda}{4\pi d}\right)^2, \qquad (1)$$

where G_t and G_r are gains of transmitting and receiving antennas, respectively, λ is the wavelength, and d is the distance between both transmitter and the receiver. Both λ and d are measured in meters and $d \geq 1$ is referred to as the RSS value. In most navigation systems, a Received Signal Strength Indication (RSSI) represents the RSS of a reference point from a transmitter, which is just another scaled representation of the RSS. Equation (1) shows that higher RSS values denote shorter signal transmission distances, by which relation, i.e., $RSS \propto \frac{1}{d^2}$, the distance between a transmitter and a receiver can be estimated. Let the receiver position be the center of a circle with radius d, and the transmitter would locate at one point on the circle locus.

We adopt the *RSS* relation equation to estimate the distance from the transmitter to the receiver. Christo Ananth et al. [13] discussed about Intelligent Sensor Network for Vehicle Maintenance System. Modern automobiles are no longer mere mechanical devices; they are pervasively monitored through various sensor networks & using integrated circuits and microprocessor based design and control techniques while this transformation has driven major advancements in efficiency and safety. In the existing system the stress was given on the safety of the vehicle, modification in the physical structure of the vehicle but the proposed system introduces essential concept in the field of automobile industry. It is an interfacing of the advanced technologies like Embedded Systems and the Automobile world. This "Intelligent Sensor Network for Vehicle Maintenance System" is best suitable for vehicle security as well as for vehicle's maintenance. Further it also supports advanced feature of GSM module interfacing. Through this concept in case of any emergency or accident the system will automatically sense and records the different parameters like LPG gas level, Engine Temperature, present speed and etc. so that at the time of investigation this parameters may play important role to find out the possible reasons of the accident. Further, in case of accident & in case of stealing of vehicle GSM module will send SMS to the Police, insurance company as well as to the family members.

Let R_l denote the l-th reader, $R_l \in \mathrm{R} = \{R_l\}_{l=1,2,...,L}$. In a RTLS, after broadcasting interrogation signals, each reader antenna R_l would receive RSSIs from reference tags, r_i s and tracking tags, t_j s, represented as S_r and S_t, respectively. For one r_i, its signal responded to the L readers can be represented as $S(r_i) = \{S_l(r_i)\}_{l=1,2,...,L}$, whose counterpart for one t_j is $S(t_j) = \{S_l(t_j)\}_{l=1,2,...,L}$. For each reader, the difference of RSS between one $r_i \in \{r_1, r_2, \ldots, r_I\}$ and one t_j is computed, which is then summed together to yield the final distance measure:

$E_i = |S(r_i) - S(t_j)| = (s_l(r_i) - s_l(t_j))2$. (2)

The distance measure is computed for all r_i s with regard to a t_j and a set of distance measure can be represented as $\mathrm{E} = E(t_j) = \{E_i\}_{i=1,2,...,I}$. A smaller E_i means that the location of the r_i is nearer to the t_j. To eliminate trivial information in estimating the location of t_j, only reference tags whose distances measures are smaller than a predefined threshold, TE, are adopted for location estimation, i.e., $\mathrm{E}_T = \{E_i \mid E_i \in \mathrm{E}, E_u < T_E\}$. These E_is in the E_T are sorted in ascending order and the smallest k elements are selected as the set of top-S nearest reference tags $\tilde{\mathrm{E}}$. The location of the t_j can then be estimated based on the through weighted average summation. The weighting is determined based on the following equation:

$\omega_i = (1/E2_i)/E_k \in \mathrm{E}(1/E2_k), \forall\ E_i \in \grave{\mathrm{E}}$.

(3)The ω_i would be larger for a smaller E_i, such that tags closer to the t_j possess heavier weights to reflect their dominance in location estimation. The location of t_j, $\grave{z}_t(j) = (\grave{x}_t(j), \grave{y}_t(j))$, can be estimated by

$\grave{z}_t(j) = \omega_i \cdot z_r(i) = \omega_i \cdot (x_r(i), y_r(i))$, (4)

where $z_r(i) = (x_r(i), y_r(i))$ is the location of r_i.

Two methods that reinforce the RTLS estimation accuracy are:

(1) *Improved LANDMARC With k Nearest Neighbors (kNN):* By eliminating trivial tag information, the RTLS can exclude those redundant r_i s to reduce the estimation error. As this LANDMARC kNN is operated based on RSSI such that different k value occasionally showed best performances. An Adaptive k-Nearest neighbor (AKN) algorithm [16] was proposed achieve higher precision performance than the original LANDMARC; (2) *VIRE System*: To improve the estimation accuracy, we can deploy more reference tags with smaller grids, but it may induce RF interference artifacts that would degrade the RSSI values. A VIRE approach [17] was proposed to filter out unlikely positions without extra reference tags, and it helps to yield more accurate object location. Locations of tjs within the grid can be estimated by dividing the original grid into smaller ones. These interposed virtual tag coordinates, acting as reference tags for the smaller grids, can help to improve estimation accuracy without additional hardware cost.

III. RFID-BASED OBJECT LOCATION IDENTIFICATION

Though the RTLS is efficient in estimating object locations, there are several challenges for it to perform perfectly. In this section, experimental results of our implemented RTLS in real environments are investigated to reveal these challenges.

A. Practical System Signal Processing Characteristics

To evaluate the LANDMARC performance, the distance estimation error is calculated to measure the accuracy performance. The error between the estimated and practical locations of t_j, $\grave{z}_t(j)$ and $z_t(j)$, is calculated by the following Euclidean distance calculation

$e(j) = |z_t(j) - \grave{z}_t(j)|$

$= (x_t(j) - \grave{x}_t(j))2 + (y_t(j) - \grave{y}_t(j))2$. (5)

Too many r_i s may not help to improve the accuracy, because r_i s far from the t_j would contribute less and even introduce errors to the final location estimation. Experiments showed that the LANDMARC cannot guarantee satisfactory estimation accuracy, whose estimation error is 0.84 m when $k = 10$.

B. Challenges

In real applications, the RF interrogation signals may subject to small-scale fading and shadowing effect, which attenuate the detected signals. The fading effect may vary at different time or place, under which the location of detected signal would be determined to be more distant to the t_j. Utilizing the RF signal power attenuation property, the RSSI is a useful metric to estimate the distance between a reader and a tag by the *Friis* equation. Non-ideal factors that map to a signal attenuated RSSI value comprise:

1) Weather Condition: An example of ambiguous RSSI mapping along a one-dimension 300-cm long distance is shown in Fig. 4. In this experiment, more than one locations demonstrate the same RSSI values. For RSSI values $-49dBm$ and $-55dBm$, they map to two different locations which are 6 and 7 units apart under different weather conditions. It also shows that the average RSSI value for sunlit days is larger than that of rainy, which are $-48.5dBm$ and $-49.2dBm$, re-respectively. Under different weather conditions [18], rain fading refers primarily to the absorption of a microwave RF signal by atmospheric rain, snow or ice.

2) Manufacturing Processes: Manufacturers of RFID tags attempt to establish various models of production technology according to hypothesis and practical measurements.

3) Interference: Interference may come from the transmitter or receiver operated in the same frequency range, external noises, or some other co-located signal systems. Tag-to-tag interference also causes RSSI variation in the RFID system. The metallic antenna of adjacent tags affects IC chip, and causes non-linear shrinkage of interrogation range.

4) Tag Collision: The RTLS is designed to periodically trigger the reader interrogation procedure, and then the reader identifies and collects tag IDs and RSSIs within a given interrogating time period. Due to tag collision, one reader cannot discriminate more than one tag IDs at the same time.

5) Path Loss: The power attenuation of electromagnetic waves will be affected by the local environment, propagation medium, and transmission distance, and is called path loss. With the attenuation of signal propagation and path loss, tags along the coverage region boundary, marked as blue squares, in different locations may be identified to be with similar RSSI values, such that its not easy to achieve accurate location estimation for the tracking tag when utilizing only RSSI values.

IV. THE PROPOSED TAG LOCATION ESTIMATION METHOD (LOCTREC)

To build a RTLS for the LOCTREC algorithm, RFID readers that provide multiple-level reader power are deployed to accurately estimate the distance between one r_i and one R_l, or between one r_i and one t_j.

A. Initial Setup

The initial setup function module is about reader interrogation and tag coverage region detection. Each of the L readers, R_l, is operated with different power, P, from low to high sequentially to detect signal coverage tag regions, $A_l(p)$s. When the RSSI value of one r_i is identified and larger than a threshold, the r_i is marked as 1 and all marked 1 tags are considered to be within the coverage region by the specified reader power. As described above, the reader interrogation signal would distribute like an ellipsoid region. For one reader R_l with $15dBm$ reader power, the detected tag area region is $A_l(1)$, enclosed by purple lines. For $20dBm$, the region would be $A_l(2)$, enclosed by green lines. The $A_l(3)$ is detected with $25dBm$ reader power. By adjusting the P-level reader power of a R_l, $P = 4$ different tag regions would be covered, i.e.,

$$A_l(p) \in \{A_l(1), A_l(2), \ldots, A_l(P)\}.$$

B. Target Object Location Estimation

This module is about the operation of the proposed LOCTREC object location estimation method. During the short interrogation time interval, responsive tag signals may collide with each other and missed. To remark the missed tags, morphological operations, dilation and erosion, are utilized on the detected tag region to recover these missed tags. The morphological OPEN and CLOSE operations [19] on a binary image, whose counterpart in our case is the anchor grid map marked with 1/0 and is denoted as G, with a structure element, B, can be represented as

$G \circ B = (G - B) \oplus B$ and $G \bullet B = (G \oplus B) - B$,

respectively. By performing the operation, $(G \circ B) \bullet B$, the original fragmented region can be made solid, in which the structure element B is a 3×3 grid square. The empty cells in Fig. 7 can be recovered and they would help the following LOCTREC processes, virtual reference coordinate estimation and camera spotting to be carried out in a more accurate way. The question mark in Fig. 9 denotes t_j s location and rectangles denote those of r_i s. When on reader, say R_l, detected the t_j in its signal coverage region with power pm, $A_l(p_m)$, the irrelevant region $A_l(p_m - 1)$ can be excluded, i.e., $C_l(p_m) = A_l(p_m) - A_l(p_m - 1)$ shown in Fig. 8. By region intersection with the counterpart of the $C_l(p_m)$ from other readers, the target tag region can be further refined, as the intersection region $C_1(3) \cap C_2(3)$ shown in Fig. 9. Location and RSSI information of tags within this refined region are used to estimate the target tag location through weighted average computation specified in (4). As compared to the LANDMARC, the number of r_i s considered to be near to the t_j can be largely reduced. As a consequence, the estimation accuracy can be improved since it would not be interrupted by far or un-correlated reference tags. In summary, the first irrelevant region exclusion and the second region intersection progressively refine the target tag region and the unstable RSSI reception can also be eliminated from multi-reader multi-power level interrogations. Performing the LOCTREC algorithm with interpolated reference tags would help to improve the estimation accuracy and is denoted as LOCTREC+. The LOCTREC+ interpolation procedure is described by the following control steps:

1) Refined Tag Collection: The remained I' reference tags,

$$r'_{i'} \in \{r'_1, r'_2 \ldots r'_{I'}\}$$

in C_{targe} in the previous example after performing the LOCTREC algorithm, are used to perform virtual reference tag coordinate interpolation. The $S(t_j)$ is also available and the location of t_j is to be estimated. In this example, I is equal to 4.

2) Virtual Tag Interpolation: Interpolate from the I reference tags for a virtual one with RSSI and location as $S(v_1)$ and $z(v_1)$, in which

$$S(v_1) = I' \omega_i \cdot \_S(r_i) \text{ and } z(v_1) = I\, \omega_i \cdot z(r_i), \quad (6)$$

where $\omega_i = 1/E2_{i'} / 1/E2_{i'}$.

3) Nearest Tags Selection: From the interpolated reference tag with $\_S(v_1)$ and $z(v_1)$, and original I reference tags,

it selects three nearest RSSI values to $S(t_j)$, and then interpolates for the second virtual reference tag $S(v_2)$ and $z(v_2)$ to approach the location of the t_j.

4) Iterative Interpolation: Repeat the operations in step 3 until the inter-tag distance between two successively interpolated tags is smaller than a predefined threshold, say n times, and the location of the last interpolated tag, $S(v_n)$ and $z(v_n)$, is considered as the best estimated location of the t_j.

C. Visual Rendering

This part is the visual rendering function that is about transforming the physical location information to PTZ camera control parameters, such that the object location can be displayed through the camera. Operation details are described below. For the context-aware smart space application deploying PTZ cameras in suitable positions, the detected object can be visually rendered. The spatial position relationship between the camera and object has to be investigated to compute the PTZ control parameters. The camera is installed at the upper corner and initially set to face the opposite corner. The three parameters: pan angle $/\_PA$, tilt angle $/\_TA$ and zoom scaling Z_{scale} are set to zero. With the estimated object coordinate $z(v_n) = (x(v_n), y(v_n))$, how to yield the three parameters to adjust the PTZ camera is described below:

1) $/\_ PA$: With $z(v_n)$ steps to estimate the $/\_PA$ are:

(i) Translate the original coordinate $(x(v_n), y(v_n))$, to the one (X_{obj}, Y_{obj}), with the camera as origin; (ii) Compute the angle $\_ A_{obj}$ by the trigonometric function, $\_ A_{obj} = \tan^{-1}(Y_{obj}/X_{obj})$; (iii) The $/\_ PA$ can be computed as $/\_ PA = 90^\circ - /\_ A_{obj}$.

2) $/\_ PA$ and Z_{scale}: (i) For $/\_ TA$, it has to compute the horizontal and direct distance from camera to object, H_{obj} and D_{obj}, respectively, i.e., $H_{obj} = (X2_{obj} + Y2_{obj})\hat{}2$ and

$$D_{obj} = ((H2_{obj} + (H_{cam} - H_{fixed})2))\hat{}2, \quad (7)$$

where H_{fixed} denotes the height of target and H_{cam} is the height of the camera; (ii) With the computed D_{obj}, the $/\_ TA$ can be estimated by:

$$/\_ TA = 90^\circ - \tan^{-1}(D_{obj}/H_{cam} - H_{fixed}); \quad (8)$$

iii) The Z_{scale} can be estimated by multiplying a scale factor to the direct distance D_{obj} in (8), i.e.,

$$Z_{scale} = Scale \times D_{obj}. \quad (9)$$

It helps to adjust the zoom scale such that the target object can be clearly displayed. The Scale value should be set properly to prevent out of focus and rendering too small target objects [20]. Figure 12 shows the PTZ camera moving toward a mobile phone and a pill bottle with two-dimensional (2D) and three-dimensional (3D) tag deployment, respectively. When there are obstacles blocking some reader antennas from interrogating tags and cameras from spotting, the other counterparts can fulfill locating and spotting the target object. As shown in Fig. 13, the pill bottle under a glass table blocked by one chair can still be located and spotted by other reader antennas and cameras.

V. SYSTEM IMPLEMENTATION AND PERFORMANCE EVALUATION

A. Experimental Setup

The practical RTLS setup and specifications are: RFID Readers (UHF RFID reader), RFID reader antenna (circularly polarized panel Antenna 902-928 MHz), and RFID tag: (EPC global Gens Tag-RFID 860-960 MHz). In our experiments, $L = 4$ reader antennas are placed at the middle of the four walls and $I = 64$ reference tags are deployed as a regular 8×8 array. As there are four antennas for one reader, to avoid interference during interrogation, the four antennas are triggered sequentially and each of them is operated with four different power levels. Fast RTLS schemes are feasible when more RFID readers are available. However, due to reader-to-tag and reader-to-reader interference problems, one passive RFID tag cannot respond to more than one reader interrogation at the same time either under different frequency interrogation signals or embedding register on tags to block specific reader interrogation signals. In our RTLS system with four readers, a two time faster scheme is feasible by independent reader interrogation on spatially disjoint tag zones. The threshold power level of tags is set to be $-57.5dBm$

from experiments to ensure the detected tags can be uniformly distributed in separated regions. The tracking tags are placed randomly with 100 times ($J = 100$). The RTLS functions [21] used for performance comparisons are shortly described below.

1) Normalized Weighting (NW): For two tags with fixed inter-distance, when their locations are close to the reader,the difference of their RSS becomes larger. This biased RSS measurement phenomenon suggests assigning smaller weights to tags that are closer to readers. For two tags with measured *RSS* values, $s1(t_j) = -20dBm$ and $s2(t_j) = -30dBm$, the former is closer to the reader and should be assigned a smaller weight. By substituting into the general formula $wl(j)$, weighting of $w1(j) = 0.4$ and $w2(j) = 0.6$ are calculated. The $s1(t_j)$ is assigned a smaller weight than $s2(t_j)$ as expected. In other words, the original formula in (2) has to be modified to accommodate this biased RSS measurement property as

$$E_i = (w_l(j) \cdot (s_l(r_i) - s_l(t_j))2)\hat{}2, \quad (10)$$

where $w_l(j) = s_l(t_j)/s1(t_j) + s2(t_j) + ... + sL(t_j)$.

2) Forsake Nearest Reader (FNR): When tags are close to a reader, the RSS values vs. distance relation becomes nonlinear. This property suggests excluding the RSS value detected by a reader nearest to the tag in calculating the distance measure. This approach is referred to as FNR, which is expected to effectively prevent large estimation errors. To be more specific, the maximum RSS value from signal strength vectors of $S(t_j) = \{s_l(t_j)\}l=1,2,...,L$ is identified and marked as $\{s_{lmax}(t_j)\}$, and (2) can be modified to

$$E_i = (s_l(r_i) - s_l(t_j))2, \quad (11)$$

where $l\_= lmax = \arg\max\{s_l(t_j)\}l=1,2,...,L$.

3) Forsake Nearest Reader With Normalized Weights(FNR-NW): By combining the advantages of above manipulations, i.e., forsaking the nearest reader to eliminate possible large error effects and utilizing normalized weights to finetune the location accuracy, the original formula for distance measure can be modified from (10) with $l\_= lmax = \arg \max\{s_l(t_j)\}l=1,2,...,L$.

4) Distance-Based LANDMARC (D-LANDMARC): Above experiments and approaches utilize (2) for location estimation, whose calculation is based on RSSI. We also implemented a distance-based LANDMARC estimation approach [22] for comparisons. Since E_i used in (3) is supposed to be a value proportional to inter-tag distance, its expected that E_i can becalculated by (11),

$$E_i = ((dl(r_i) - dl(t_j))2)\hat{}2, \quad (12)$$

where $dl(r_i)$ is the distance of the *l*-th reader to the a r_i (known) and $dl(t_j)$ is the distance of the *l*-th reader to a t_j (unknown). This approach is called the distance-based LANDMARC. However, only $s_l(r_i)$ and $s_l(t_j)$ are available (or $s_l(r_i) - s_l(t_j)$ as used in (2)), derivation from which to yield the $dl(t_j)$ is required. For simplicity, the operation is assumed to be applied in a free space, and the *Friis* equation can be utilized, i.e.,

$$RSS\ (\text{dB}) = 10 \log Pr(d)$$
$$=10(\log Pt + \log Gt + \log Gr) + 20 \log(\lambda/4\pi d). \quad (13)$$

The term $s_l(r_i) - s_l(t_j)$ can be represented as

$$[20 \log(\lambda/4\pi dl(ri)) - 20 \log(\lambda/4\pi dl(t_j))], \quad (14)$$

Which implies that $dl(tj)=dl(ri)\times10(sl(ri)-sl(tj)/20)$.

B. Simulated RTLS Performance Evaluation

To simplify the analysis for feasible program simulation, we assume: 1) All tags and RFID readers are ideal and identical in terms of signal processing capability; 2) The signal attenuation is proportional to distance in a free space, e.g., no signal interruption and tag collisions, such that the *Friis* equation can be utilized; 3) All tags can receive reader signal, i.e., the RSSI used in the *Friis* equation; 4) With assumptions above, the RSS values can be calculated by the *Friis* equation. The experimental setup, comprising device specification, environmental conditions, simulation interface description and location regions, is the same as that in the LANDMARC. For these RTLS functions, it needs to specify the *k* value for all methods, excluding LOCTREC and AKN algorithms. Simulation performances demonstrated that: 1) In the LANDMARC (0.36 m), the tag coverage boundary artifact cannot be eliminated since no tag location information is involved. Only utilizing signal strength to perform the RTLS function cannot provide accurate estimation. 2) In FNR (0.28 m), the RSS of the nearest reader is excluded in that it would induce highly non-linear dominance in the estimation process. As shown, the estimation error is smaller than the previous ones by adopting this approach. 3) The problem encountered by adopting the nearest reader RSS can be solved by utilizing the NW procedure to reduce the dominance of nearest reader RSS. As shown in Fig. 14, both NW (0.35 m) and FNR-NW (0.28 m) benefit from utilizing this procedure. 4) In AKN (0.14 m), as a proper *k* value is determined to exclude trivial reference tag information, the estimation accuracy can be improved. Although the performance is satisfactory, it can be further improved by the proposed LOCTREC method that utilized the reference tag location information. 5) In VIRE (0.1 m), it utilizes the virtual grid mechanism to linearly interpolate for the RSS values to increase virtually the tag deploy density. Simulation results show that the estimation error can be further reduced as compared to the FNR. Though it helps to improve the estimation accuracy, its time complexity is higher than others. However, since the RSS values would be decayed nonlinearly with distance, the linear interpolation cannot afford to yield this non-linear decay property. 6) The proposed

LOCTREC (0.07 m) inherently utilizes the tag location information in performing the RTLS function such that an obvious performance improvement can be found, as compared to previous approaches that utilize only RSS values. 7) By utilizing the VIRE procedure, the improved LOCTREC, LOCTREC+ (0.05 m), can further improve the estimation accuracy. It also shows that the triangle type virtual tag interpolation yields the least estimation error.

C. Practical RTLS Performance Evaluation

When the reader set detected the region that t_j resides, say $C_{target} = \forall\ i,m\ C_i\ (m)$, it then applied the LANDMARC procedure on the C_{target} to estimate the location of t_j. The practical estimation errors of different methods are provided. 1) Since the LANDMARC approach (0.84 m) only considers RSS for location estimation, tags locate at coverage region boundary of interrogation signal would lead to estimation error. 2) This boundary tags artifact cannot be well eliminated in the NW approach because tag location information is not well utilized. As shown in Fig. 14, both LANDMARC and NW (0.84 m) demonstrate high estimation error. 3) The FNR approach (0.82 m) and FNR-NW approach (0.80 m) improve estimation performance slightly in that it partially eliminates the boundary tag artifacts problem and unexpected signal artifacts. 4) The D-LANDMARC approach (0.79 m) utilizes the value proportional of both tags RSSI as their distance, but due to unstable RSSI reception it would not eliminate the boundary tag artifacts problem. 5) The AKN approach (0.63 m) still suffers the artifacts of coverage boundary tags and demonstrates limited improvement in estimation accuracy. 6) The VIRE approach (0.50 m) benefits from virtual grid interpolation and leads to improved estimation accuracy. However, the linear interpolation cannot accommodate the non-linear relationship between signal strength and distance. Although the estimation error can be largely reduced, the VIRE approach demonstrates higher time complexity as compared to others. 7) The proposed LOCTREC (0.24 m) utilizes the tag location information in the estimation procedure and needs not to set a proper k value to yield high estimation accuracy. As shown in Fig. 15, the LOCTREC demonstrates the best location estimation performance as compared to others and the LOCTREC+ (0.15 m) can further improve the accuracy. The most distinguished feature of the LOCTREC is that boundary tag artifacts can be well eliminated, such that further interpolation operation can largely reduce the estimation error.

VI. CONCLUSION AND FUTURE RESEARCH

One accurate RFID-based indoor object location estimation method, LOCTREC, is proposed in this paper. Power level adjustable RFID readers are adopted to perform location estimation. With adjustable reader power, the intersection of neighboring tags to the tracking one among different reader interrogation range regions can be identified and the estimation accuracy can be largely improved. In additional to improving the RTLS prediction accuracy, we proposed to integrate a real-time video surveillance system with the RTLS to spot the target object by PTZ cameras. Contributions of this paper comprise: 1) A RFID-based object location identification method is proposed to estimate the target object location. Its carried out by deploying passive tags and utilizing RFID readers with adjustable interrogation range. The proposed method effectively excludes irrelevant tags to reduce the number of reference tags to estimate the target object location. The location estimation error can be largely reduced as compared to previous RTLS methods; 2) The estimated target object location can be rendered by intuitive camera spotting. The control parameters of PTZ camera are computed based on the estimated location and space camera setup relation. In general, the RTLS estimation error can hardly be alleviated under dynamic environments. A major advantage of LANDMARC is its robustness to environmental change, but its estimation performance depends on how to select a good k value to eliminate trivial information involved in the RTLS estimation procedure. The proposed LOCTREC algorithm effectively removes this k value dependency and yields more accurate estimation results. Notwithstanding the RTLS methods are robust, how to maintain accurate estimation under unpredictable environmental change is still a challenging problem. As the impact on RSSIs of tracking tag and its neighboring tags would be different from the same environmental changes, how to well utilize both RSSI and location information for accurate RTLS prediction under changing environment is considered as our future research. In addition, how to eliminate reader-to-reader and reader-to-tag interference of one multi-reader RTLS is also an interesting research topic.

REFERENCES

[1] H.-Y. Yu, C.-H. Lee, R.-C. Chang and J.-J. Chen, “Toward developing a human-environment communication scheme for elegant steering wheel chairs,” in *Proc. 25th World Battery, Hybrid Fuel Cell Electr. Vehicle Symp. Exhibit.*, Nov. 5–9 2010. vol. 22, no. 4, pp. 558–570, Apr. 2011.

[2] A. Baumann *et al.*, “A review and comparison of actions for habitual video observation systems,” *EURASIP J. Image Video Process.*, vol. 19, no. 5, pp. 329–343, 2008.

[3] M. N. K. Boulos and G. Berry, “concurrent locating systems (RTLS) in healthcare: A condensed primer,” *Int. J. Health Geographic.*, vol. 11, no. 1, p. 25, Jun. 2012.

[4] H.-Y. Yu and J.-J. Chen, "An intelligent space location identification scheme based on submissive RFID tags," in *Proc. Int. Conf. Mach. Learn. Cybern.*, vol. 1, Jul. 2014, pp. 428–433.

[5] A. Aboodi and T.-C. Wan, "estimate of WiFi-based inside (WBI) positioning algorithm," in *Proc. 3rd FTRA Int. Conf. Mobile, Ubiquitous, Intell. Comput. (MUSIC)*, Jun. 2012, pp. 260–264.

[6] M. Bouet and A. L. dos Santos, "RFID tags: Positioning main beliefs and localization techniques," in *Proc. 1st IFIP Wireless Days*, 2008, pp. 1–5.

[7] H. Jeffrey and B. Gaetano, "Spot ON: An inside 3D position sensing expertise based on RF signal strength," Dept. Comput. Sci. Eng., Univ. Washington, Seattle, WA, USA, Tech. Rep. 2000-02-02, Feb. 2000. [Online] Available: http://www-di.inf.puc-rio.br/~endler/ courses/Mobile/papers/LPS/spoton.pdf, accessed May 2015.

[8] L. M. Ni, Y. Liu, Y. C. Lau, and A. P. Patil, "LANDMARC: inside position sensing using dynamic RFID," *J. Wireless Netw.-Special Issue, Pervasive Comput. Commun.*, vol. 10, no. 6, pp. 701–710, Nov. 2004.

[9] S.-L. Ting, S. K. Kwok, A. H. C. Tsang, and T.-S. Ho, "The study on using unreceptive RFID tags for inside positioning," *Int. J. Eng. Bus. Manage.*, vol. 3, no. 1, pp. 9–15, 2011.

[10] Y. Zhao, Y. Liu, and L. M. Ni, "VIRE: dynamic RFID-based localization using effective situation removal," in *Proc. Int. Conf. Parallel Process.*, Sep. 2007, p. 56.

[11] Propagation Data and Prediction Methods Required for the Design of Earth-Space Telecommunication Systems, ITU-R, Rec. P.618–11, Nov. 2013.

[12] J. Serra, "Introduction to mathematical morphology," *Comput. Vis. Graph. figure Process.*, vol. 35, no. 3, pp. 283–305, 1986.

[13] Christo Ananth, C.Sudalai@UtchiMahali, N.Ebenesar Jebadurai, S.Sankari@Saranya, T.Archana, "Intelligent sensor Network for Vehicle Maintenance system", International Journal of Emerging Trends in Engineering and Development (IJETED), Vol.3, Issue 4, May 2014, pp-361-369

[14] C.-H. Yeh and S.-F. Su, "Enhance LANDMARC from the fundamentals," in *Proc. Int. Conf. Adv. Robot. Intell. Syst.*, May/Jun. 2013, pp. 23–27.