# Integrating RFID Signal with Scene for Automatic Identification in Logistics and Production

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**Abstract** With the booming e-commerce development, advanced industrial logistics technique is necessary to enhance its working accuracy and efficiency. Meanwhile, the demand of Auto Guidance Vehicles (AGVs) is increasing while the technique can be popularized to apply in logistics and production. However, the AGV is necessary to work with precise technology for enhancing its performance. Therefore, the demands on the automatic identification and localization with RFID technology for supporting logistics and production are raising and it becomes the most important. In this chapter, the RFID technology integrating into the indoor positioning technology with LANDMARC methodology is studied. Moreover, the virtual reference elimination (VIRE) algorithm that is based on LANDMARC algorithm is applied to advance the performance of RFID localization. The VIRE positioning method is added with virtual reference tags to improve the accuracy of positioning in this study. This chapter summarizes three main contributions in this methodology. First, the RFID localization is more cost-efficiency in logistics and production, because it is no need to consider additional readers and tags. The hardware cost is the same as in the case of both LANDMARC and VIRE systems, so the accuracy can be easily improved in the comparison with LANDMARC. Second, the estimated position of target tags are more accurate because it works with virtual tags for localization. Third, the VIRE system can better adapt to dynamic indoor scenarios than the LANDMARC system in real environments.

**Keywords** RFID localization · LANDMARC · Virtual reference elimination (VIRE) · Auto guidance vehicles (AGVs)

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## 1 Introduction

Online shopping is rapid development in the life and industries. Therefore, the logistic development is rapidly increasing into new generation. It is necessary to concern for enhancing its efficiency. Most of the logistic industries has been changed to use Auto Guidance Vehicles (AGVs) to instead of traditional human operation. However, the performance of AGV is being studied to more precise. Some researchers are considering to apply the Vision based Simultaneous Localization and Mapping (vSLAM) technique to optimize the transportation path for AGV (Wong and Yu 2019a). Meanwhile, the professional software is also supported to enhance the performance of logistics management (Wong and Yu 2019b). However, some logistic companies are not considered to use AGV with vSLAM technique because of cost-efficiency. Radio frequency identification (RFID) has been widely used in supporting the logistics management special in applying big data approach for logistics trajectory discovery (Zhong et al. 2015). Moreover, it is also applied in the RFID logistics system applicable to ubiquitous-city (Hong and So 2009). The general cargo handler logistics had studied to enhance the performance by the RFID technique with human error consequences (Giustia et al. 2019). Therefore, logistics and production are increasing the demand of AGVs with RFID technology. The LANDMARC methodology is recently referenced for the positioning algorithms with RFID technology (Ho and Wong 2012), the coordinates of readers and reference tags are known and the target tags can be calculated by different weights of them. The virtual reference elimination (VIRE) algorithm that is based on LANDMARC algorithm is applied to advance the performance of RFID localization, virtual tags are used to replace the reference tags in LANDMARC which can reduce the noise between tags and enhance the accuracy as more points can be used to calculate.

LANDMARC algorithm, utilizes Received Signal Strength Indicator (RSSI) to track moving objects, was the first attempt using active RFID for indoor location sensing with satisfactory result. In order to increase accuracy, it utilize the reference tags as reference points to assist readers in locating the unknown tracking tags, is one of the most classic algorithm using RFID for indoor location. LANDMARE contributed an idea of estimate the coordinates of tracking tags by comparing their RSSI values with those of k-nearest reference tag at known coordinates. Apparently, more reference tags means tracking tag located with greater precision. At the same time, excessive amount of reference will not only increase cost, but also introduce expected radio frequency interference, which led to inaccuracy of positioning.

For overcoming this defect of LANDMARC, VIRE introduce a concept of "virtual reference tags" to obtain more likely accurate positions without additional cost. The real reference tags in LANDMARC are properly placed to form a 2D regular grid. This real regular grid is further divided into $n \times n$ equal sized virtual grid cells, and each virtual grid cells are treated as covered by four virtual reference tags. The RSSI of virtual reference tags is calculated from those real reference tags by linear interpolation algorithm. The whole sensing area is divided into a number of location regions, which the centre of each region correspond to a virtual reference tag. Every reader has its own proximity map. If the difference between the RSS measurement of the unknown tag and the RSS measurement of a region is smaller than a threshold, the region is marked as 1. The fusion of all the n readers' maps provides a global proximity map for the tag.

In this paper, the VIRE positioning method is studied and further validated for supporting the advanced performance with RFID technology in logistics management. The RFID localization is cost-efficiency in logistics and production as no additional readers and tags is required. Meanwhile, the estimated position of target tags is more accurate because it works with virtual tags. The VIRE system can better adapt to dynamic indoor scenarios than the LANDMARC system in real environments. It is focused to discuss and compare the VIRE system with the LANDMARC system in the static and dynamic situation in this paper.

## 2 Methodology

The experiment of RFID localization system is applied UHF RFID technology. In this technology, the tags could be identified by the reader which shows by the identification code. The reader could also show the RSSI (Signal Strength Indication). It is decreased by the free path space loss. With the theory of the LANDMARC formula. The location of the tags could be found. The LANDMARC formula is using statistics to work out the probable location. It contrasts the reference resources and the test tags for providing the most probable location of the test tags. In this paper, it is combined with LANDMARC formula and image processing to match the test tags in the real scene with the identification code. In order to calculate the location more accuracy, it is put forward the VIRE system that matches the test tags in real scene.

The RFID Reader is RF-CODE 443 MHz M250 Reader that receives and reports the radio frequency messages emitted by RF Code tags. Its read range is around 45 m. The M100 asset tags have 2 s motion alert and 10 s beacon time. The dynamic part in the experiment is very important, so the M100 asset tags are chosen. The experiment needs a high-speed stimulant which near to 60 km/h. Therefore, the simulation car is applied and instead of AGV. The stimulation car is the simplest one with a detection tag. The traction engine is an electric engine which work in 24 V. Its rated speed could be 20,000 Rev. It's a powerful traction engine. The high speed of the engine makes the traction line in a horrible speed. The traction line is designed away from the engine, otherwise, the engine is easy to wound by the traction line. Thus, the roller and bearing system are designed to solve this problem. The holder is used to simulate the real situation of the reader. In the real situation, the reader on the warehouse will put upon the AGV. The Logitech C270 HD IPTV webcam is used to photographed and judge the location of the simulation car. In the software development is applied to Node.js, because it is an open-source, cross-platform runtime environment for developing server-side Web applications.

The real reference tags are properly placed to form a 2D regular grid. Objective tags can be placed anywhere within gird. In order to improve the precision of tracking tags within gird's position. Thus, the gird should be divided into a finer gird based on the concept of virtual reference tags. The core of VIRE approach is that four real reference tags as per physical grid and then divided into n x n equal sized virtual gird cells. The coordinate of virtual reference tags to be defined on the basis of the coordinate of the four real reference tags are known. On the RSSI values of virtual reference tag, the approach suggests the linear interpolation algorithm to obtain the RSSI values.

To obtain the RSSI value of each virtual reference tag to each reader, therefore, the reference tags' RSSI value and coordinate position are known in advance. Thus, the RSSI values of virtual tags are interpolated by the formula below:

$$S_k\left(T_{P,b}\right) = S_k(T_{a,b}) + \mathrm{p} + \frac{S_k(T_{a+n1,b+n2}) - S_k(T_{a,b})}{n+1} \\ = \frac{p \times S_k(T_{a+n1,b+n2}) + (n+1-p) \times S_k(T_{a,b})}{n+1} \tag{1}$$

where $S_k(T_{i,j})$ represents the RSSI value of the virtual reference tag located at the coordinate $(i, j)$ for the $k$th reader. Assuming there are $\mathrm{N} \times \mathrm{N}$ virtual reference tags, the complexity of the interpolation algorithm is O ($\mathrm{N}^2$).

Therefore, the coordinate position of all real reference tags and virtual reference tags are known. On the other hand, the signal strength of all real reference tags and virtual reference tags also are known. Meanwhile, it is important to choice the ideal threshold value $k$th in the LANDMARC algorithm to obtain the localization of objective tags by the ideology of LANDMARC algorithm:

$$E_j = \sqrt{\sum_{i=1}^{n} (\theta i - Si)^2} \tag{2}$$

where $j \in (1, \mathrm{m})$. The nearer reference tag to the tracking tag has a smaller E value. When there are m reference tags, an tracking tag has the vector $\mathrm{E} = (\mathrm{E}_1, \mathrm{E}_2, \ldots\ldots \mathrm{E}_\mathrm{m})$. These E values are used to reflect the relations of the tags, the smallest $E_j$ means that the reference tag is the nearest reference tag surrounding the tracking tag. K-reference tags which have relative lower E values are selected from the m reference tags as the $k$ neighbors. The tracking tag's coordinates are estimated by computing the weighted average of the $k$ neighbors' coordinates (Fig. 1):

$$(x, y) = \sum_{i=1}^{k} wi(xi, yi) \tag{3}$$

$$\mathrm{wi} = \frac{1}{\mathrm{E}_\mathrm{i}^2} / \sum_{\mathrm{i}=1}^{\mathrm{k}} \frac{1}{\mathrm{E}_\mathrm{i}^2} \tag{4}$$

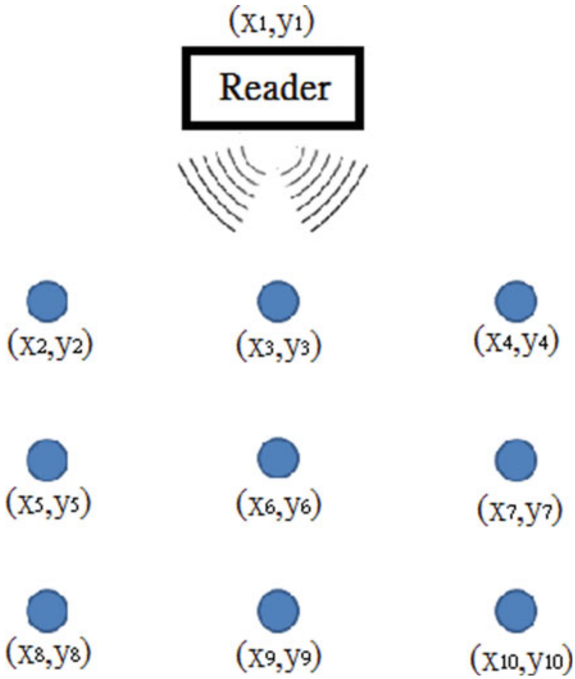


**Fig. 1** The RFID localization system setup

## 3 Results and Discussion

The experiment of this research is included four parts which are the factor affecting the RSSI value, the database of reference tags, objective tags being matched at rest and objective tags being matched at dynamic. The experiments are done the same environment and condition. However, it is focused to discuss and compare the VIRE system with the LANDMARC system in the static and dynamic situation in this paper, because it can show the main contributions for logistics management. As a result, the objectives tags are matched by the VIRE system which can more accurate than the LANDMARC system and Log-path loss models.

It had been determined the RSSI data from the ten random object tags. In this discussion, it is put forward the VIRE system which matched ten object tags in the static situation and compared with LANDMARC system in the static situation. The virtual reference tags are obtained though the formula (Eq. 1) that includes interpolated concepts. On the other hand, to confirm the data based on VIRE system is regarding to the LANDMARC system. Nevertheless, the VIRE system is different for the LANDMARC system because the VIRE approach adopts much more virtual reference tags. In this two type of database, the main location method both are the weighting algorithm. The database of LANDMARC system has real 192 data. On the contrary, the database of VIRE System has 620 data which be divided into 192 real data and 428 virtual data.

$$\text{There are error rate: } \sigma = \frac{\text{VIRE coordinate} - \text{Real location coordinate}}{\text{Real location coordinate}} \quad (5)$$

As the results of Tables 1, 2, and 3, it can obtain that the error rate of VIRE system is lower than the error rate of LANDMARC system. In the X-axis, the average error of VIRE is 25.81% and the LANDMARC is 33.36% regarding Table 4. In the Y-axis, the average error of VIRE is 15.27% and the LANDMARC is 21.88% according to Table 4. Some results using VIRE positioning system has some error up to only 1% for X-axis. However, some particular data, the error rate has suddenly increased up to 106.21% for instance (0.45, 24 m) that may be affected by irregular factors, such as scattering or surrounding material. Meanwhile, the error rate of VIRE system has the error up to only 1.54% for Y-axis. Nevertheless, some particular data, the error

**Table 1** The real location and VIRE location of ten random tags

| Tag CODE | Real coordinate | RSSI | VIRE location (coordinate) | Error rate X (%) | Error rate Y (%) |
|---|---|---|---|---|---|
| LOCATE00365552 | (2, 3) | (−62, −59) | (2.023, 3.073) | 1.15 | 2.43 |
| LOCATE00365554 | (2, 4) | (−63, −62) | (1.937, 4.426) | 3.15 | 10.65 |
| LOCATE00365555 | (2.5, 5) | (−65, −65) | (2.075, 5.143) | 17.00 | 2.86 |
| LOCATE00365569 | (1.5, 5) | (−65, −68) | (2.001, 8.132) | 27.96 | 62.64 |
| LOCATE00365556 | (2, 8) | (−66, −68) | (1.980, 8.512) | 1.00 | 6.21 |
| LOCATE00365562 | (1.5, 12) | (−79, −75) | (2.776, 14.369) | 85.03 | 5.74 |
| LOCATE00365561 | (2, 18) | (−73, −74) | (2.027, 13.514) | 1.35 | 24.90 |
| LOCATE00365559 | (3, 24) | (−89, −88) | (2.585, 26.909) | 13.80 | 4.62 |
| LOCATE00365560 | (1, 25) | (−89, 86) | (2.224, 25.387) | 106.21 | 1.54 |
| LOCATE00365557 | (2, 28) | (−77, −81) | (1.935, 16.816) | 1.42 | 31.07 |

**Table 2** The real location and LANDMARC location of ten random tags

| Tag CODE | Real coordinate | RSSI | LANDMARC location (coordinate) | Error rate X (%) | Error rate Y (%) |
|---|---|---|---|---|---|
| LOCATE00365552 | (2, 3) | (−62, −59) | (2.150, 2.830) | 7.50 | 5.67 |
| LOCATE00365554 | (2, 4) | (−63, −62) | (2.170, 5.480) | 8.50 | 37.00 |
| LOCATE00365555 | (2.5, 5) | (−65, −65) | (1.960, 6.120) | 21.60 | 22.40 |
| LOCATE00365569 | (1.5, 5) | (−65, −68) | (1.890, 8.140) | 26.00 | 62.80 |
| LOCATE00365556 | (2, 8) | (−66, −68) | (2.070, 7.360) | 3.50 | 8.00 |
| LOCATE00365562 | (1.5, 12) | (−79, −75) | (2.960 11.610) | 97.33 | 3.25 |
| LOCATE00365561 | (2, 18) | (−73, −74) | (2.620, 12.320) | 31.00 | 31.55 |
| LOCATE00365559 | (3, 24) | (−89, −88) | (2.410, 25.590) | 19.67 | 6.62 |
| LOCATE00365560 | (1,25) | (−89, 86) | (2.170, 23.780) | 117.00 | 4.88 |
| LOCATE00365557 | (2, 28) | (−77, −81) | (2.030, 17.730) | 1.50 | 36.67 |

**Table 3** Error rate comparison between LANDMARC and VIRE

| Real coordinate | Error rate X VIRE (%) | Error rate Y VIRE (%) | Error rate X LANDMARC (%) | Error rate Y LANDMARC (%) |
|---|---|---|---|---|
| (2, 3) | 1.15 | 2.43 | 7.50 | 5.67 |
| (2, 4) | 3.15 | 10.65 | 8.50 | 37.00 |
| (2.5, 5) | 17.00 | 2.86 | 21.60 | 22.40 |
| (1,5, 5) | 27.96 | 62.64 | 26.00 | 62.80 |
| (2, 8) | 1.00 | 6.21 | 3.50 | 8.00 |
| (1.5, 12) | 85.03 | 5.74 | 97.33 | 3.25 |
| (2, 18) | 1.35 | 24.90 | 31.00 | 31.55 |
| (3, 24) | 13.80 | 4.62 | 19.67 | 6.62 |
| (1, 25) | 106.21 | 1.54 | 117.00 | 4.88 |
| (2, 28) | 1.42 | 31.07 | 1.50 | 36.67 |

**Table 4** The average error rate of VIRE and LANDMARC

| | X-axis (%) | Y-axis (%) |
|---|---|---|
| VIRE | 25.81 | 15.27 |
| LANDMARC | 33.36 | 21.88 |

rate of VIRE system has suddenly increased up to 62.64% for instance (0.95, 4 m) that may be affected by irregular factors too. Thus, the indoor environmental factor will be influenced with experimental error that will be studied in the further research as noise cancellation. It is shown that the VIRE system is more suitable for the real environment measurement comparing with LANDMARC system.

It had been obtained the empirical log-distance path loss formula in the VIRE database. In this discussion, it is analysed the method of VIRE System which compared with the empirical Log-distance path loss methods that are y express RSSI value and x express distance (Table 5).

From the Tables 6 and 7, the VIRE error rate is lower than the error rate of empirical Log-path loss models. The VIRE system can be matched the location of objective tags by the RSSI value, but the empirical Log-distance path loss only obtained the distance of Y-axis. Compared with the empirical Log-distance path loss models, the VIRE system is more suitable for locating in the real environment measurement.

In the experiment of dynamic identification in real scene, the RFID VIRE system is connected with the real scene to match the RFID signal with the image signal. The camera catches the image signal with the probable location. With the probable location and the RFID signal, the VIRE location matches with the probable location. The image signal can be matched with the RFID signal. For simulating the real scene in the high speed logistic operation, the testing simulation car should be assigned to different velocities which may be even to 60 km/h. Assume the range of the RFID is 20 m, in consideration of the fastest detection interval of the RFID reader is 3 s. The

**Table 5** The experiment data with Log-distance path loss method of VIRE database

| Location | Channel A | | Channel B | |
|---|---|---|---|---|
| 0.45 m X-axis | y = −7.225ln(x) − 55.064 | $x = e^{\frac{y+55.064}{-7.225}}$ | y = −7.312ln(x) − 52.805 | $x = e^{\frac{y+52.805}{-7.312}}$ |
| 0.95 m X-axis | y = −7.297ln(x) − 53.484 | $x = e^{\frac{y+53.484}{-7.297}}$ | y = −7.041ln(x) − 52.732 | $x = e^{\frac{y+52.732}{-7.041}}$ |
| 1.45 m X-axis | y = −7.565ln(x) − 50.305 | $x = e^{\frac{y+50.305}{-7.565}}$ | y = −6.675ln(x) − 52.268 | $x = e^{\frac{y+52.268}{-6.675}}$ |
| 1.95 m X-axis | y = −8.088ln(x) − 50.624 | $x = e^{\frac{y+50.624}{-8.088}}$ | y = −6.814ln(x) − 53.237 | $x = e^{\frac{y+53.237}{-6.814}}$ |
| 2.45 m X-axis | y = −8.669ln(x) − 52.278 | $x = e^{\frac{y+52.278}{-8.669}}$ | y = −6.892ln(x) − 56.247 | $x = e^{\frac{y+56.247}{-6.892}}$ |

**Table 6** Calculated path loss at different locations

| Real location (m) | RSSI | The distance of log path loss, Channel A | | The distance of log path loss, Channel B | |
|---|---|---|---|---|---|
| (1.45, 2) | (−62, −59) | $x = e^{\frac{y+50.305}{-7.565}}$ | 4.69 m | $x = e^{\frac{y+52.268}{-6.675}}$ | 2.74 m |
| (1.45, 3) | (−63, −62) | $x = e^{\frac{y+50.305}{-7.565}}$ | 5.35 m | $x = e^{\frac{y+52.268}{-6.675}}$ | 4.30 m |
| (1.95, 4) | (−65, −65) | $x = e^{\frac{y+50.624}{-8.088}}$ | 5.91 m | $x = e^{\frac{y+53.237}{-6.814}}$ | 5.62 m |
| (0.95, 4) | (−65, −68) | $x = e^{\frac{y+53.484}{-7.297}}$ | 4.85 m | $x = e^{\frac{y+52.732}{-7.041}}$ | 8.74 m |
| (1.45, 7) | (−66, −68) | $x = e^{\frac{y+50.305}{-7.565}}$ | 7.96 m | $x = e^{\frac{y+52.268}{-6.675}}$ | 10.56 m |
| (0.95,11) | (−79, −75) | $x = e^{\frac{y+53.484}{-7.297}}$ | 33.01 m | $x = e^{\frac{y+52.732}{-7.041}}$ | 23.63 m |
| (1.45, 17) | (−73, −74) | $x = e^{\frac{y+50.305}{-7.565}}$ | 20.09 m | $x = e^{\frac{y+52.268}{-6.675}}$ | 25.94 m |
| (2.45, 23) | (−89, −88) | $x = e^{\frac{y+52.278}{-8.669}}$ | 69.13 m | $x = e^{\frac{y+56.247}{-6.892}}$ | 100 m |
| (0.45, 24) | (−89, −86) | $x = e^{\frac{y+55.064}{-7.225}}$ | 109.62 m | $x = e^{\frac{y+52.805}{-7.312}}$ | 93.67 m |
| (1.45, 27) | (−77, −81) | $x = e^{\frac{y+50.305}{-7.565}}$ | 34.08 m | $x = e^{\frac{y+52.268}{-6.675}}$ | 57.83 m |

highest velocity which must be detected to connect with this formula: S = Vt. The S is the range of the RFID, and the t is the detection interval. The fastest velocity V = 6.67 m/s which is 24 km/h. It means in this experiment the fastest velocity is 24 km/h.

The Simmah AR925 tachometer will be used to test the velocity of the simulation car. The Logitech C270 HD IPTV webcam instead of the camera on the warehouse.

The first experiment the tachometer shows that the velocity is 67.52 m/min which is 4.0512 km/h. The detection program is shown that:

**Table 7** Error rate comparison between VIRE and the empirical log-distance path loss model

| Real location, coordinate | Error rate X of VIRE (%) | Error rate Y of VIRE (%) | Error rate Y of Log path loss (Channel A) (%) | Error rate Y of Log path loss (Channel B) (%) |
|---|---|---|---|---|
| (1.45, 2 m), (2,3) | 1.15 | 2.43 | 134.5 | 37 |
| (1.45, 3 m), (2,4) | 3.15 | 10.65 | 78.3 | 43 |
| (1.95, 4 m), (2.5,5) | 17.00 | 2.86 | 47.8 | 40.5 |
| (0.95,,4 m), (1,5,5) | 27.96 | 62.64 | 21.25 | 118.5 |
| (1.45, 7 m), (2,8) | 1.00 | 6.21 | 13.71 | 50.86 |
| (0.95, 11 m), (1.5,12) | 85.03 | 5.74 | 200 | 114.82 |
| (1.45, 17 m), (2,18) | 1.35 | 24.90 | 18.18 | 52.59 |
| (2.45, 23 m), (3,24) | 13.80 | 4.62 | 200.57 | 334.78 |
| (0.45, 24 m), (1,25) | 106.21 | 1.54 | 356.75 | 290.29 |
| (1.45, 27 m), (2,28) | 1.42 | 31.07 | 26.22 | 114.19 |

LOCATE00365566 1f0 760 −83 −90, 6:18:09 pm
LOCATE00365566 1f0 760 −77 −87, 6:18:12 pm
LOCATE00365566 1f0 760 −75 −79, 6:18:15 pm
LOCATE00365566 1f0 760 −54 −68, 6:19:18 pm

With the VIRE location shows that in the 6:18:12 pm the simulation car is in the (18.329, 2.029) which means the car is 17 m from the camera. In the camera the simulation car is near 17 m from the camera. The match test is successful.

The second experiment the tachometer shows that the velocity is 141.62 m/min which is 8.4972 km/h. The detection program is shown that:

LOCATE00365566 1f0 760 −85 −85, 6:37:06 pm
LOCATE00365566 1f0 760 −78 −84, 6:37:09 pm
LOCATE00365566 1f0 760 −50 −50, 6:37:12 pm

With the VIRE location shows that in the 6:37:09 pm the simulation car is in the (18.3014, 2.0252) which means the car is 17 m from the camera.

The third experiment the tachometer shows that the velocity is 555.24 m/min which is 33.3144 km/h. The detection program is shown that:

LOCATE00365566 1f0 760 −88 −79, 11:52:09 am

LOCATE00365566 1f0 760 −82 −84, 11:52:12 am
LOCATE00365566 1f0 760 −50 −50, 11:52:16 am
LOCATE00365566 1f0 760 −51 −53, 11:52:20 am

With the camera it is found that the simulation car starts at 11:52:13 am., and the simulation car reaches destination before 11:52:16 am. The VIRE location can only detect the location on the start and the end. It means that if the velocity is too high than 24 km/h, so it could not match the moving car on the RIFD range. In this experiment, it found out the limitation of dynamic situation.

The fourth experiment the tachometer shows that the velocity is 253.2 m/min which is 15.192 km/h. The detection program is shown that:

LOCATE00365566 1f0 760 −83 −88, 12:26:24 pm
LOCATE00365566 1f0 760 −83 −88, 12:26:27 pm
LOCATE00365566 1f0 760 −57 −68, 12:26:30 pm
LOCATE00365566 1f0 760 −51 −50, 12:26:34 pm

With the VIRE location shows that in the 12:26:30 pm the simulation car is in the (8.0747, 2.1636) which means the car is 7 m from the camera.

The VIRE system can calculate the coordinate of object tags through the RFID Signal. Combining the location of object tags in the scene, it can match the location of the moving object tags. If the velocity of car over 24 km/h, the system could not match the moving car on the RIFD range (20 m).

## 4 Conclusions

In this paper, it integrated VIRE with LANDMARC system to locate the position of the simulation car that instead of AGV. In reality, an open area on the high speed could greatly reduce the effect of the electromagnetic reflection, so as to enhance the accuracy of the positioning. When applied in practical, more readers can also be used to ensure the accuracy of the RFID signal and thus the direction and position of the target tags. Therefore in order to guarantee a better result when using this system on the road, readers with less restriction, i.e. faster detection speed and wider detection range should be used. However in the open area the weather becomes another vital factor influencing the behaviour of the electromagnetic wave, for instance tempest, mist, thunderstorm etc. Because of the environment and technical restriction it was not able to simulate this kind of variety.

Another route to achieve a better reliability and accuracy is to combine image analysis with the RFID signal. This methodology requires a prerequisite database which records the information of the simulation cars in the respective tags. In this way the system would filter incompatible matching pair when a tag is detected within the range. As a result, the objectives tags are matched by the VIRE system which can more accurate than the LANDMARC system and Log-path loss models. Moreover, the hardware cost is same as the LANDMARC system and VIRE system can improve the accuracy under the same situation as LANDMARC. Meanwhile, the estimated position of objective tags is more accurate because it works with virtual tags to define the more unknown position.

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