



GUI Simulation Platform for RFID Indoor Tracking System

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Received: 28 February 2014 /Accepted: 30 June 2014 /Published: 31 July 2014

Abstract: This paper gives a platform of simulation data for RFID indoor tracking system, i.e., tracking system graphical user interface. The platform contains input and output interface, and the former includes the radius settings, data generation module and the user guide. The corresponding output interface includes system parameters display and the saving image function, etc. The default parameters are also given for the graphical user interface (GUI) of the RFID indoor tracking system. The analysis of the user's use shows that the developed platform is practical and feasible. *Copyright © 2014 IFSA Publishing, S. L.*

Keywords: GUI, RFID, Data generation, Tracking, Simulation platform.

1. Introduction

Radio frequency identification (RFID) can obtain distance information, it has been used for many indoor tracking systems recently [1-2]. As an important issue for the RFID indoor tracking, the simulation system has attracted great interest, especially the tracking system interface simulation platform.

The main purpose of the interface for RFID indoor tracking system is to generate simulated RFID data, which is important to the research or the RFID tracking system [3-4]. Because of the complex of the test field, various factors need to take into account to describe the RFID measurement data [5-6]. Sometimes data acquisition has become a big problem for research of tracking target. This platform can simulate RFID indoor tracking system data comprehensively. What's more, this interface will be used in subsequent issues, and its operability and effectiveness will be further verified in the external field test.

RFID stores and retrieves data through the electromagnetic transmission to a RF compatible integrated circuit. It fundamentally consists of two elements: the reader and the tag on the target to be identified and tracked. Once the tag gets close to the reader, the distances between the tag and readers are extracted from received signal strength information (RSSI) [7]. The information carried by the tag and its distance from the reader will then be obtained and sent to the data processing center. In the actual research of the indoor tracking algorithm, the algorithm performance will often be influenced because the measurement data model is inaccurate sometime [8-9]. Moreover, the real value of the actual trajectory is also difficult to obtain. Therefore, design a simulation platform applied for algorithm development has great value.

The graphical user interface (GUI) is a new type of interface development approach different from the VC or Java. Its vivid expression of GUI in the algorithm demonstration or in field experiments have played a significant role. For researchers who

familiar with Matlab and do not want to write a lot of code in VC, Matlab / GUI is undoubtedly the best programming choice. As GUI not only can be embedded in an existing simulation program, but also can dynamically present a human-computer interaction to the operator or customer, which make it possible to provide an operator interface for those who are not familiar with Matlab. One more advantage of Matlab language is the powerful matrix operations, which make it widely used in the study of algorithms. What's more, Matlab played a significant role in the algorithm docking technology.

In the environment of VC and Java interfaces development platform widely used, MATLAB / GUI has win much attentions of the researchers by its unique technological advantage. We also have to admit that MATLAB / GUI is mouse weaker than VC interface when it comes to interactive and dynamic display, but the superiority of signal management functions are irreplaceable, especially in data processing works. A simple MATLAB statement may spend an hour of work for VC developer to achieve it. It is helpful to process a large number by means of MATLAB powerful matrix calculation functions. The use of large matrix to organize and reconstruct data in a short time is more difficult to deal with by VC operation.

There is a bright spot on the exterior of GUI interface that is the graphics effect. Embedded MATLAB GUI can support all of the graphics processing functions, including two-dimensional drawings and three-dimensional graphics functions. Like the grid, contour line, image fills and other effects can be used by execute a statement. And MATLAB also supports graphic scene, which is when the graphics rendering is finished, you can call the internal scene menu as needed to edit graphics.

Graphical user interface (GUI) is a user interface of the window, including the cursor buttons, menus, texts and other object configurations. Through a certain way (such as a mouse or keyboard) users can select, activate these graphic objects, and then the computer will produce some actions and cause changes, such as implementing computing, graphics and so on.

In Matlab, the graphical user interface is a graphical object that contains a variety of interfaces, the typical graphical interface including graphics field, function button space, and user-defined feature menus. When the user activates the corresponding GUI object can perform the appropriate actions.

As is well known, all objects can be written in the Matlab by the M-file. GUI is also a Matlab object, so you can use the M-file to create GUI. M file is the most basic method to create a GUI, and if you create a graphical interface by using other methods to implement various functions of the graphical controls, an appropriate code of M file is also needed.

In addition to using M file to create a GUI object, the Matlab also provides a graphical interface for users to develop a convenient and efficient integrated development environment: Matlab graphical user

interface development environment which referred GUIDE, which mainly a design tool set.

Matlab GUI supports all the user controls are integrated together, and provides the interface appearances, attributes and behaviors in response to the setting method. You can also save the designed GUI interface as a FIG resource file, which will automatically generate a corresponding M-file. The M-file will contain initialization code and the formation of GUI control code interface layout.

As to the FIG file, it contains the graphics window of GUI and fully described its child objects and attributes information of all related objects. By calling "hgsave" command or using M file editor as "File>Save" command the file can be generated. FIG file is a binary file that contains serialized graphic window object. Properties of all objects are created in the graphics window when the user saved properties. The most primary function of the file is to save the object handle.

While M File contains GUI design, control callback functions mainly used to control various features of the GUI when unfolded. The file is basically a callback function which can be divided into two parts as the user GUI initialize data and the callback function, and the callback controls can be called depend on the specific interactions of the GUI. Application of M-file use "openfig" command to display GUI object, but the file does not contain the design code of the user interface, the corresponding codes can be saved by FIG file.

GUI simulation for the RFID tracking system is developed here. The user interface consists of a variety of graphical objects such as buttons, text boxes, menus and the other control objects. On this interface, the user can use the mouse to activate these controls to create interface objects, modify objects in the attribute editor, get a required handle objects by the 'findobj' function and program the corresponding callback function.

The platform is designed with RFID reader modules to optimize measurement accuracy, making it possible to accurately set the measurement. By setting the parameters of the object the input interface achieve the interaction between user and the computer. The output interface analysis the tracking system through the form and image. On this platform, the simulation results of different number of readers and different measurement radius of the tracking system show the effectiveness and practicality of this platform. The using flowchart of the platform is as Fig. 1.

2. Design Principles

Software system always has different requirements, but the starting point for the design and the ultimate goal are the same. In general, the design of the interface should comply with the following principles: simplicity, consistency, common property.

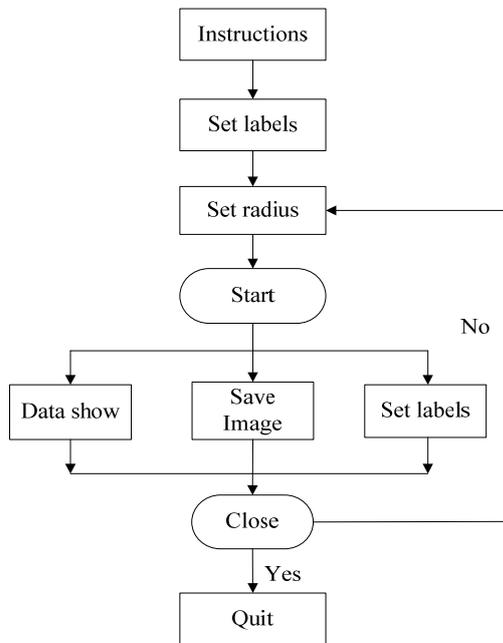


Fig. 1. The functional block diagram of the simulation platform.

1) Simplicity.

Simple is required in the interface design, and the interface will be more attractive to reflect the main features and performance of the surface directly and clearly.

2) Consistency.

Consistency has two meanings. First, the authors should develop their own style of interface to be as consistent as possible. Secondly, the newly designed interface with other existing interface style should not completely opposite to the existing interfaces.

3) Common property.

This property requires the interface should include the familiar functions, signs and symbols, which will surely make users feel friendly and familiar.

3. MATLAB / GUI General Production Steps

Interface designing includes interface design and production program. The specific production steps are as follows:

- 1) Analysis the main features and understands the design tasks very well;
- 2) Draw a sketch interface, and examine it from the user's point of view;
- 3) Produce (static) interface on the software according to the sketch and check it;
- 4) Program the dynamic interface function procedures and test it;

These are just general principles. In the design, there are often crosses between the steps. The process of design and implementation is often not in one step.

4. Measurement Model of RFID

We firstly discussed the RFID measurement model, which is the main simulated part in the simulation part. RFID measured signal level model based on the average RSS, decreasing logarithmically with distance and log-normal shadowing. Then by the signal level model, the distance and the error can be obtained. The error mean and standard deviation grow proportionally to the estimated distance.

The distance $z_n(t_i)$ between the n th reader and the tag at sampling time t_i can be got by RSSI nominal value $P_n(d, \phi, t_i)$

$$z_n(t_i) = d_0 10^{\frac{P_r(d_0) - P_n(d, \phi, t_i)}{10q}}, \quad (1)$$

where d_0 is the close-in reference distance, $P_r(d_0)$ is the RSSI in dBm units with the reference distance d_0 and q is the path loss exponent.

Let X , \dot{X} and \ddot{X} be the target location, velocity, and acceleration along the horizontal axis direction, while Y , \dot{Y} and \ddot{Y} are the corresponding variables along the longitudinal axis direction. Then the state variable of the system at time t_i can be expressed as

$$x(t_i) = [x(t_i) \quad \dot{x}(t_i) \quad \ddot{x}(t_i) \quad y(t_i) \quad \dot{y}(t_i) \quad \ddot{y}(t_i)]^T, \quad (2)$$

Let $d_n(t_i)$ be the actual distance between the n th reader and the tag at sampling time t_i . We can see the actual distance $d_n(t_i)$ is the function of the state $x(t_i)$.

$$d_n(t_i) = \sqrt{(x(t_i) - x_n(0))^2 + (y(t_i) - y_n(0))^2}, \quad (3)$$

where $x_n(0)$ and $y_n(0)$ are the horizontal and vertical coordinates of RFID readers, $x(t_i)$ and $y(t_i)$ are the real location of the target in the 2D tracking space.

In general the distance $z_n(t_i)$ and the actual distance $d_n(t_i)$ are not identical, the measurement error must be considered:

$$z_n(t_i) = d_n(t_i) + v_n(t_i), \quad (4)$$

where $v_n(t_i)$ is the measurement noise of the n th RFID reader at the sampling time t_i with the measurement covariance satisfying

$$v_n(t_i) / d_n(t_i) \sim N\left(0, \left(\frac{0.2303\sigma_p}{\gamma}\right)^2\right), \quad (5)$$

where σ_p is the standard deviation, γ is the path loss exponent, $d_n(t_i)$ is the distance between the

target and the n th RFID reader and ‘ / ’ means division calculation. We can see that the ratio of ranging error to the actual distance follows a normal distribution with a zero-mean and a standard deviation of $\frac{0.2303\sigma_p}{\gamma}$. The standard deviation of the received power σ_p can be fixed at 4 dB, which is about the average of the reported standard deviations for wireless communications. The path loss exponent γ is usually between 1.6 and 6.5 based on actual measurement.

5. Platform Model and Problem Description

The simulation data generation platform of RFID indoor tracking system based on MATLAB mainly needs to resolve the following four major issues: 1) set the measuring radius; 2) set coordinate system labels; 3) instructions of the platform for use; 4) data generation, storage and display modules. What’s more, this platform GUI model is established by the M-file, and the following gives a platform for the default parameters simulation of RFID indoor tracking system.

5.1. The Initial Main Interface

Run the M-file can get the initial main interface of RFID indoor tracking system simulation data platform, Fig. 2 can be got, with the platform function controls, and data generating coordinates. The parameters needed for the tracking are the note of the coordinate system, the x, y coordinates of the position of RFID readers, the measurement accuracy (radius), the actual positions of the moving objects, and the distance between readers and measurable targets.

5.2. Instructions

The platform designs a control to introduce the GUI system for first-time users. The M-file made it in the form of text performance in the sub-interface. Click “Instructions” button can call the function of “text” and then appears the sub-interface as Fig. 3 shows.

5.3. Set Radius

The simulation data platform needs the reader to simulate measurement range, so the setting of the radius measurement is needed. This platform can measure the radius from 0 to 5000. To meet user’s demand, the platform creates dialog box to allow the users input radius. The format of the call as follows:

```
answer = inputdlg (prompt, name,
numlines, default);
```

The answer is a string cell array, which is used to store user inputs. “prompt” is for the prompt string, while “name” is or the title of the dialog box and “numlines” sets the maximum number lines for user to input. The answer stores the default input string as 50. The dialog form shows in Fig. 4.

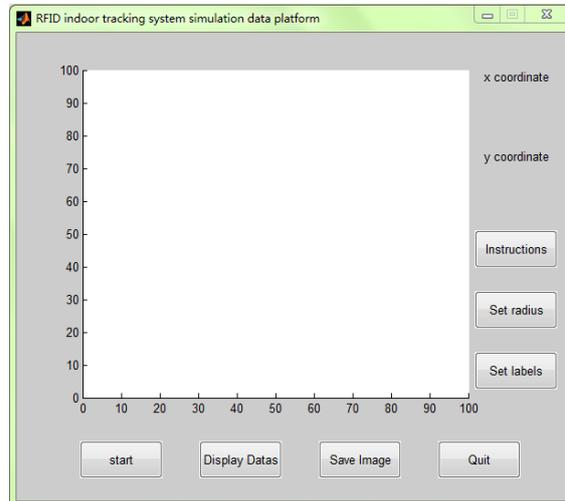


Fig. 2. RFID indoor tracking system simulation platform.

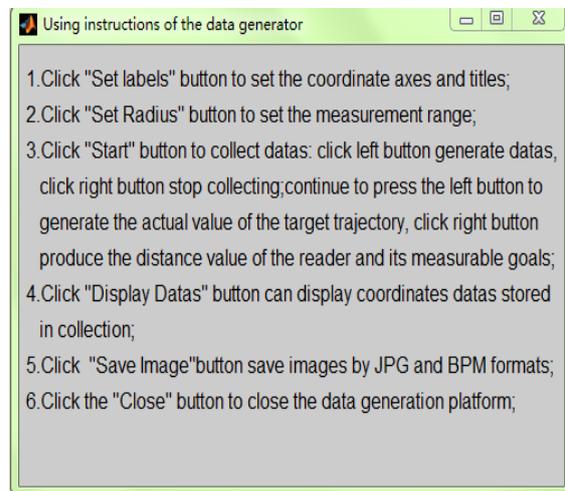


Fig. 3. Instructions.

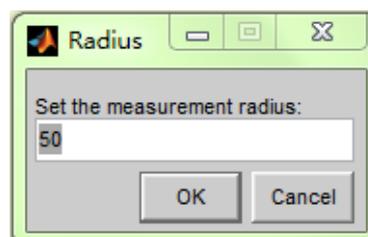


Fig. 4. Set Radius.

5.4. Set Labels

The purpose of this feature is that the user can enter any character custom labels in the dialog box to change the coordinate system theme. The achieved setting dialog box codes as follows:

```
prompt={'Set Title Name:','Set abscissa Name:',...
        'Set ordinate Name:'};
name='labels';
numlines=1;
defaultanswer={'RFID','x','y'};
answer=inputdlg(prompt,name,numlines,defaultan
                swer);
```

The result is shown in Fig. 5.

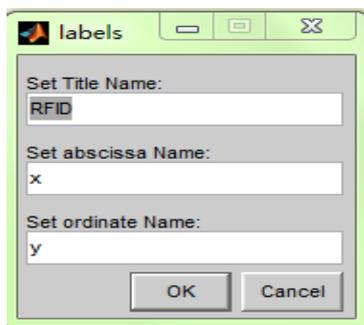


Fig. 5. Set Labels.

5.5. Start

This module implements the data collection by the "ginput" function, making the coordinate system interact with the .m function.

This control successfully simulated the RFID indoor tracking system, whose main functions are as follows: the generation, display, storage of the data. That is to say the location coordinates values of the RFID reader and the actual moving targets are displayed and stored in real time. What's more, the distance data between reader and its measurable targets can generate and store.

The parameters this function considered can vividly simulate the actual system, which means the platform has a good usability. Fig. 6 shows the detailed operation flow chart.

As shown in Fig. 6, with the default parameter setting (radius is 50, coordinate axis respectively set as X, Y and RFID) the detailed system operation are as follows: click the "Start" button, the cursor changes to "+" shape, then click the left mouse button, you can set the position of readers, The platform can display and store the coordinate positions of the readers in real-time. Click the left mouse button as many as you want, the platform can offer 255 readers at most. When the reader is set up, right-click, and in the end reader position is set to

produce a certain radius precision measurement range contour map.

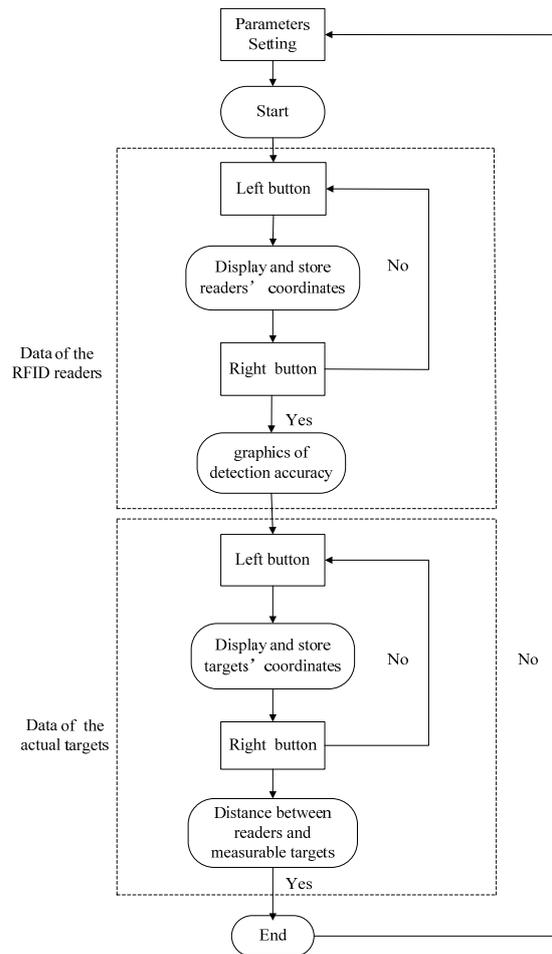


Fig. 6. The detailed operation flow chart of Start.

Click on the left button continues to produce the actual movement of the target location information, the real-time display and store location coordinates are available. When the simulation finished, right-click to end, the platform will automatically calculate and store the distance between the reader and its measurable objectives.

Fig. 7 shows the result of the RFID indoor tracking system simulation data generation platform under the default parameters.

In this image, the position of "x" analog the position of RFID reader in the room, while the color contour radius means the monitoring area when the radius is 50 and the RFID readers are fixed on the right location. The deeper the color, the higher the detection rate is. Moreover, the star line is the actual trajectory that the RFID indoor tracking system produced. Meanwhile, the module can store coordinate data of the RFID readers and the real trajectory targets in excel files, which made it possible to display data. The simulations of the target trajectory have shown in Fig. 7 and Fig. 8 with the

radius as 30 and 120, respectively. From Fig. 7 and Fig. 8, Figure 9, we can see if there are only few RFID readers, the tracking system could only monitor small range and the detection rates will be low. In general, the larger radius, the more RFID readers lead the more dense of the positions, then there will be greater scope of the monitoring indoor tracking system and higher detection rate.

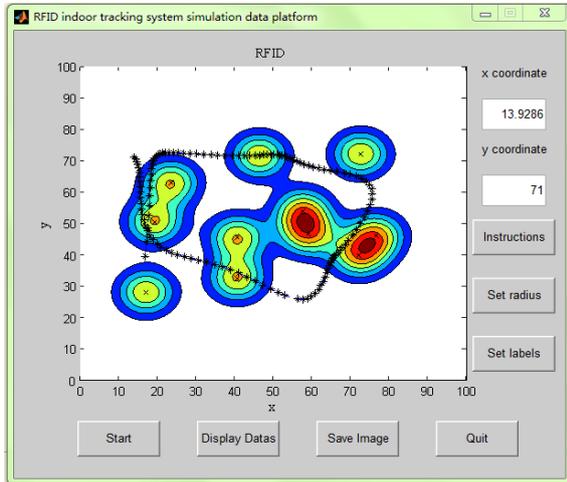


Fig. 7. The system of default parameters.

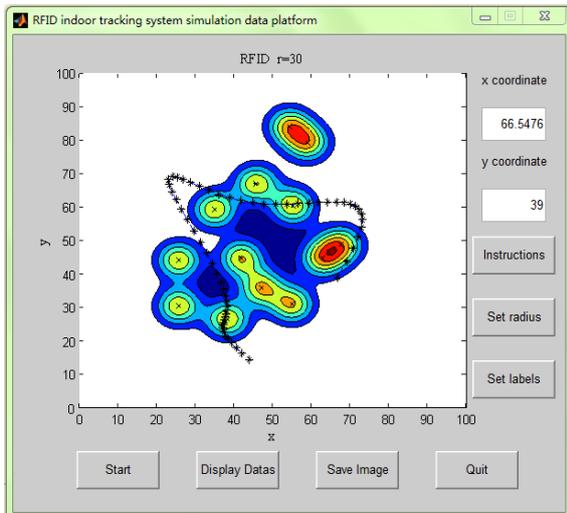


Fig. 8. The target trajectory with the radius 30.

5.6. Display Data

The module can display and store the generated data. In the data generation stage of the RFID indoor tracking system, the readers, the real target trajectory and the measurement data between the RFID readers and targets are stored in Excel tables named as data.xls, truedata.xls and RFIDdata.xls, respectively. Data can be read by calling the function “xlsread”.

By creating a data display window, the GUI displays three types of data in tabular form. This window also retains “save”, “edit”, “view”, and other

functions. Fig. 10 shows the corresponding data display window of Fig. 9.

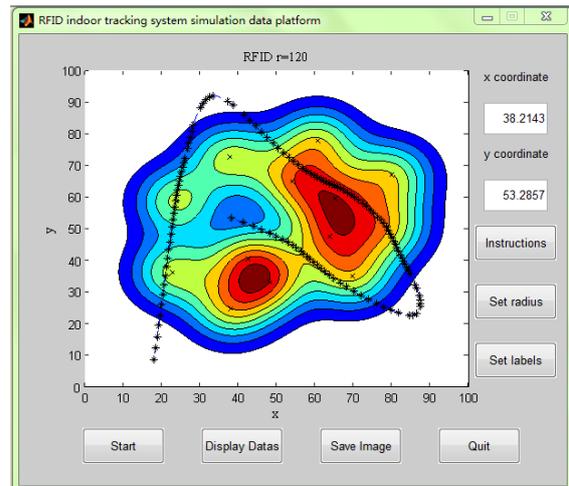


Fig. 9. The target trajectory with the radius 120.

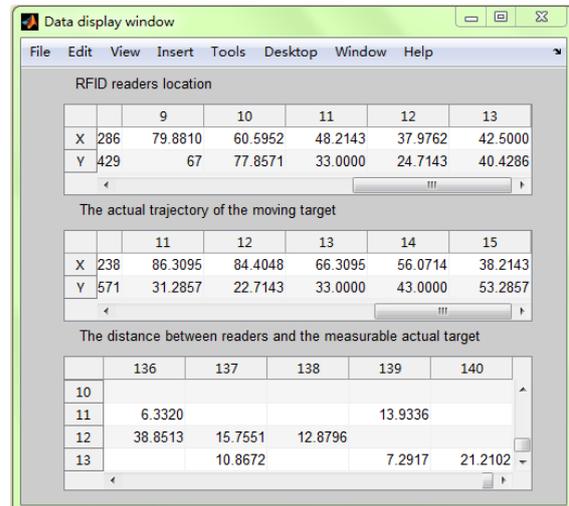


Fig. 10. Data display window.

In the Fig. 10, the table named as “RFID reader location” stores the obtained location data of 13 readers (x coordinate, y coordinate) in this RFID simulation system. The first row of the table indicates the position of the set readers, and its total number is apparent and obtainable. The second and third rows are designed to display location coordinates for the readers. Each reader has its X-axis and Y-axis coordinate values. This simulation actually generates 13 readers at total.

The table named as “The actual trajectory of the moving target” stores the position of the real trajectory targets coordinates. As the first table shows, this table also gives three rows, whose second and third rows mean the location coordinates for the actual moving targets while the first row means the actual location coordinates of the moving target.

Unlike the table, some of the values of targets are generated by click the button, but others are generated by interpolation, which make it easier for users to get enough data to imitate the actual trajectory of the moving target. This simulation set 15 targets at total and interpolated 125 measurements of actual targets. Then the whole number is reached 140.

The table named as “The distance between readers and the measurable actual target” gives the system measured the distance between readers and the targets. It is this table that combined the previous two tables. The column represents the each measurement of the actual targets, and the row represents readers. As for the first column, it sequentially displayed the 13 readers. And the first raw shows the 140 targets sequentially too. Take the 136 column for example, the 10 and 13 raw is empty, that means reader 10 and 13 can’t detect the 136 target, while reader 11 and 12 away from the 136 target 6.3320 and 38.8513 respectively.

In order to show these data more clearly Table 1 and Table 2 are given the total data stored e first two tables of Fig. 10 shows. And table 3 partly gives the data corresponding to the third table of Fig. 10 shows.

Table 1. The RFID reader location.

	1	2	3	4	5
X	22.7381	23.92857	37.7381	53.92857	65.11905
Y	36.14286	58.71429	72.71429	65	59.57143
	6	7	8	9	10
X	63.69048	69.64286	78.92857	79.88095	60.59524
Y	47.57143	35	50.14286	67	77.85714
	11	12	13		
X	48.21429	37.97619	42.5		
Y	33	24.71429	40.42857		

Table 2. Some measurement of the moving target.

	1	2	3	4	5
X	17.97619	21.54762	24.16667	27.02381	33.45238
Y	8.714286	40.71429	62.14286	77	91.85714
	6	7	8	9	10
X	47.5	59.64286	67.2619	77.02381	82.02381
Y	78.71429	66.71429	62.14286	52.71429	41.85714
	11	12	13	14	15
X	86.30952	84.40476	66.30952	56.07143	38.21429
Y	31.28571	22.71429	33	43	53.28571

5.7. Save Image

The completed RFID indoor tracking system simulation platform often needs to be referenced in other documents. To facilitate access to images, the software designed features to save the images, we can save the image to achieve common fig and bmp format by calling the function:

```
[fName, pName, index] = uiputfile ({'* .jpg.';
    '.*bmp'}, 'Save Picture As');
```

Table 3. Part of the measurement data.

	131	132	133	134	135
1					
2			21.54448		
3			37.17871		
4	20.88988	28.41453	9.008235		10.94473
5			19.59475		
6	13.75939		6.253911		
7		19.36873	22.37324		27.04773
8					
9				39.77863	
10					
11	10.07533		16.03653	9.431669	16.50779
12	26.49263				
13	14.8501		11.1587		11.29014
	136	137	138	139	140
1			15.22355		
2					24.6837
3			30.49411	9.206304	
4	8.669296	21.63065		16.53725	
5	19.30482				
6					21.03676
7	22.52293				
8			15.00303	47.6725	
9				46.54545	
10					
11	6.331984			13.93361	
12	38.85132	15.75514	12.87958		
13		10.86721		7.291662	21.21022

The platform also create a message dialog box to prompt the file has successfully saved. Fig. 11 shows the dialog vividly.

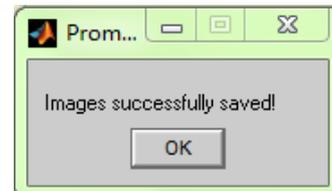


Fig. 11. Prompt.

The program can prompt dialog box to save the image, and the saved images of jpg, bmp format shown in Fig. 12, Fig. 13, respectively.

5.8. Quit

This module creates a question dialog to further confirm if calling the function:

```
questdlg ('? Confirmation to exit the current window',
    'exit confirmation', 'Yes', 'No', 'No');
```

The results shown in Fig. 14. To clear all data, the functions are as follows:

```
clear all; close all; clc;
```

Click “Yes” then the software is closed, or the software can continue to work.

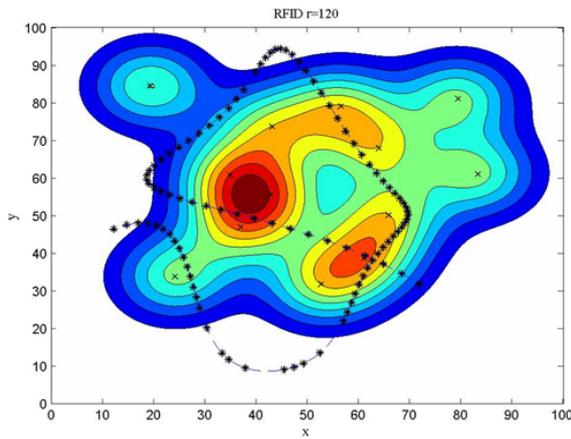


Fig. 12. The saved image with jpg format.

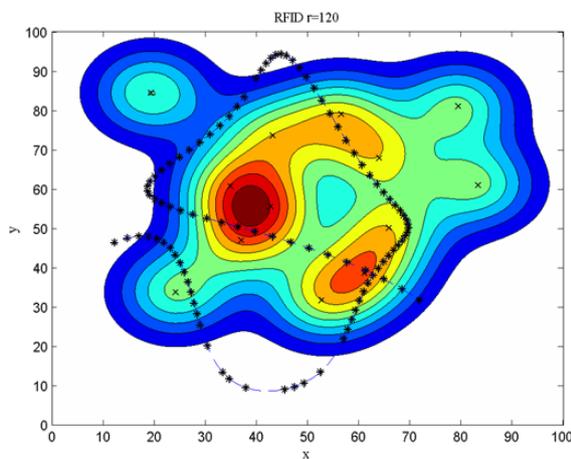


Fig. 13. The saved image with bmp format.

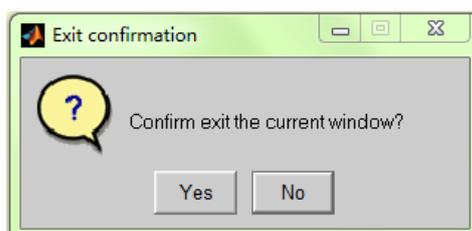


Fig. 14. The exit dialog.

6. Conclusions

Thanks to MATLAB GUI development tool, the RFID indoor tracking system data simulation platform is created, allowing the system to clearly and vividly show the graphical simulation results to the author or the customers.

All in all, for some frequently used data generation work, this platform is undoubtedly an efficient alternative tool.

Acknowledgments

This work is partially supported by NSFC under Grant No. 61273002, 60971119 and the Importation and Development of High-Caliber Talents Project of Beijing Municipal Institutions No. CIT&TCD201304025.

References

- [1]. Ranasinghe (Australia), Chao-Chuan Tang, Yan-Qing Shao, Heng Wang, Networking RFID Application Solutions in Many Fields, *Machinery Industry Press*, 2013, pp. 56-70.
- [2]. Huan-Sheng Ning, RFID Major Projects with National Networking, *Peking University Press*, 2012, pp. 132-145.
- [3]. Xi Cheng, RFID Application Guide - User-oriented Application Mode, Standards, Coding and Hardware Choice, *Electronic Industry Press*, 2011, pp. 176-182.
- [4]. Yi Xu, Jian-Jun Chen, *RFID Principles and Applications*, *Tsinghua University Press*, January, 2013, pp.153-187.
- [5]. Jian-Liang Gao, Jian-Ju He, RFID Principles and Techniques in Networking, *Electronic Industry Press*, July, 2013, pp. 167-174.
- [6]. Hao Wang, Networking Contact-RFID Technology Applications and Patent Cases, *Science Press*, December, 2010, pp. 74-89.
- [7]. Wei Zhang, Quan Gan, UHF RFID Tag Antenna Design, Simulation and Practical, *Electronic Industry Press*, 2012, pp. 137-146.
- [8]. Jun-Yi Zhou, Jing Shi, A comprehensive multi-factor Analysis on RFID localization capability, *Advanced Engineering Informatics*, Vol. 2011, pp. 32-40.
- [9]. Cheng-Gan Shan, Yu-Feng Shan, Lei Yao, Radio Frequency Identification (RFID) Principles and Applications, *Electronic Industry Press*, Beijing, December, 2012, pp. 78-83.