A Novel Automatic Evaluation System for Testing Radio Frequency Identification Applications

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Abstract—The number of radio frequency identification (RFID) applications in different fields is increasing rapidly. The test technical for RFID application become important research hot point because of some RFID solutions lost. A novel automatic evaluation system for testing RFID applications is designed which has capability to test RFID solution automatically. At first, the function necessary of the testing system are analyzed, and the framework is proposed. Then, a RFID application about wine anti-counterfeit is evaluated based on proposed testing system. Test results are presented. It indicates that proposed testing system is useful and effective.

Keywords—RFID; automatic evaluation; anti-counterfeit; optimization

I. INTRODUCTION

With the advantage in non-contact, interference and the ability of identification a number of items, Radio Frequency Identification (RFID) is becoming the best and the most extensive application of the technique in the field of automatic identification. RFID applications on different industries such retail, supply chain, warehouse management, logistics, manufacturing, and military are increasing in number[1]. Recently, RFID techniques have been used in various fields, like tracking, logistics/supply chain, and transportation. According to a market analysis[2], the market value will reach 20 billion in China in 2011. RFID has become a new and exciting area of technological development, and is receiving increasing amounts of attention.

However, while they have striven hard for applying RFID into business application, the success rate of data read/write in RFID application system usually can not reach 100%. RFID involves the utilization of the electromagnetic spectrum to transmit data. Environment complexity will influence the data transmit between antenna and tags. The RFID application developer used to reduce the test term due to the lack of understanding of the importance of testing, frequent errors often occurred during the RFID application implementation. The RFID application testing technology has becoming increasingly important due to the variety of RFID technology and complexity of its application environment. Zeng et al. discuss that how to improve performance of the deployment of RFID application based on the deployment simulator [4]. Porter et al.[5] developed a test protocol with eight different radio RFID systems. Two major categories of tests were administered: laboratory baseline performance tests and warehouse passive interference tests. Some testing equipments and system were developed for RFID application. The functions of these RFID testing systems include identification scope of RFID reader, location of RFID equipment, the tags selection, etc. The testing approaches and systems aforementioned are manual. During testing the RFID application, it can only implement the testing tasks one by one. Because of the complexity of RFID application, it is highly desired to developed automatic testing approach and system. Several factors for influencing RFID application can test in one time. In this study, based on the concept integration testing and unit testing [3], we propose an automatic evaluation system for testing RFID application. The key issues in the RFID application are analyzed, and the architecture of the evaluation system and main components are discussed.

II. FRAMEWORK OF TESTING SYSTEM

A. Function Analysis

The functions of automatic testing system for RFID application include data collection, equipment controlling, tasks management, and data analysis.

1) Data collection

Data collection is classified two types. The one is collecting the data of RFID tag. Another is the environment data. The data in tags can be transmitted to
RFID reader when the tags entered into the scope of reader. The number of tags would be multiple or only one. Some factors influence the data capture in RFID application. We call these factors as environment data which include temperature, humidity, electric field and magnetic field values around reader.

2) Equipment Control

Some equipment’s parameters take important role in RFID solution, such as the angle of antenna, the power of RFID reader, the speed of tags, and so on. Meanwhile, some environment factors also influence the effect of RFID application. These factors include temperature, humidity, and Electromagnetic interference. The equipment’s parameters and environment factors can be adjusted automated through controlling the equipment in the testing system.

a) controlling RFID reader

In a RFID solution, RFID readers are controlled to work or sleep according to the work process. In this testing system, we should simulate the function of controlling RFID reader same as the function in RFID solution.

During the test process, the RFID reader’s work status, power can be changed automatically. The parameters and the results are deposited in the

b) controlling automatic testing equipment

The test parameter can change automatically through controlling testing equipment. A RFID antenna rotate control facility is designed to control the angle of RFID antenna.

3) Tasks management

The testing process for a RFID solution is a complexity one. Before execute a test task, we should make a task plan. Thus, we need the function of task management that mainly take charge of build a new task, modify an existed task, and delete a task. A complexity task might be composed by some unit testing tasks which corresponding to typical scenario. When build a large testing task, we can select some small tasks to assemble. The management of unit tasks is also necessary function in task management module.

4) Databanks and data analysis

When a RFID solution is tested, the RFID reader read/write data from/to RFID tags attached in goods. Meanwhile, the sensors detect the environment parameters. All data are deposited in databank. There are three databanks in the testing system. The first one is simulator data databank where hold the standard data created by simulator. The second one is middleware data databank where save the data detected in testing process. The last one is result data databank. The detected data are analyzed by statistic analysis module. Then the result data are deposited into result data databank.

After all data collected are saved in middleware databank, the function of data analysis can be implemented. In this testing system, user can write data analysis algorithm or data analysis rules according to the RFID solution. This open method for user building algorithm is similar to the S function in Matlab.

5) RFID solution Optimization

An optimization module for RFID solution is designed in this testing system. In the past few decades, evolutionary algorithms [6,8-9] have been successfully applied to real-world optimization problems. The main advantage of these algorithms, relative to most conventional optimization methods (e.g., Newton-based techniques, linear programming, and interior point methods) lies in that they do not apply mathematical assumptions to the optimization problems and have better global search capabilities [10]. An evolutionary algorithm, genetic algorithm, has been used as optimization algorithm in this module. The results of data analysis are the values of fitness function, and the parameters controlled by automatic control equipments are used as optimized values. The optimization process is illuminated in Fig. 1.

6) Result Report

The testing results are saved in the results databank. Finally, a report is made to show the testing results.

B. Testing System Framework

The framework of testing system for RFID solution is illuminated by Fig.2. The framework is composed
several function modules which are corresponding to the functions. These function modules are, RFID middleware module, statistic analysis module, parameter controlling module, optimization module, algorithms module, report module, respectively.

1) Data interface modules

The data interface modules include RFID reader interface, sensors interface, and controller interface. The RFID reader interface is the data interface for reading and writing by RFID reader from RFID tags. The testing system could control the RFID reader through the RFID reader interface. Sensors interface is the data channel that transmits the data detected by sensors in RFID solution. The controller interface take charge of controlling the automatic control equipments. The control parameters are sent into that equipment through the controller interface.

2) RFID middleware module

In the testing system, the RFID middleware module contains the logic of the RFID application [7]. The RFID middleware include RFID reader controller, Data collector and Business logic modeling tool. RFID reader controller could control all RFID readers to work, to close, to sleep, and to wakeup. Data collector could record all data achieved by RFID reader. It can identify the data received by which RFID reader, and create the RFID events. Business logic modeling tool provide user the tool for logic modeling according to the business logic of RFID solution. In this way, the testing system could become a flexible system that suit for various RFID solution.

3) Statistic analysis module

The RFID data collected by data collector is entered into the statistic analysis module. The analysis algorithm is selected from algorithms module according to the test task. The original data from testing process and analyzed data by statistic analysis are saved in middleware databank. The results are put into report module, and create report. The result data are deposited into the results databank.

4) Optimization module

After statistic analysis, the results are not only saved in middleware databank but also are sent into optimization module. During the optimization process of Genetic algorithm (see the process in Fig. 1), the new parameters population is created. Those new control parameters are sent to parameters controlling module as input data. Then, the automatic control equipment could change the parameters in RFID solution. In this way, we can give some suggestions to enhance the performance of RFID solution.

5) Parameters controlling module

In this RFID solution testing system, automatic control equipment could change some parameters about RFID reader, air condition, and so on. This module takes charge of controlling all machines based on the parameters optimized.

6) Report module

When the test task finished, the testing system can create a report according to report format. The report module has the function to manage report format. To print report is also an important function of report module.

Figure 3. the framework of RFID solution testing system
III. CASE STUDY

In order to validate proposed testing system, a RFID solution is used.

A. Description of the RFID solution

Recently, RFID technique becomes widespread use Anti-counterfeiting techniques for wine. The information within tags can only write one time. Through scan the tags, the buyer can authenticity identify the wine that want to buy, and can know the product time, factory, etc. Here, we use the RFID solution of intelligent product line for Anti-counterfeiting techniques to test the proposed system.

The RFID tag is included in the bottle lid of the wine. On the product line, two RFID readers are placed. The one is writer, and another is reader. The information about the wine is written by the writer. When the wine bottle is moved to the place of the RFID reader, the RFID reader read the information to validate if the information written into the tag. If the information couldn’t read, then the PLCs control the machine to remove the wine bottle from the product line. The logic of test process is illuminated in Fig.4.

The RFID reader used in the intelligent product line is CSL-461 which frequency range is from 845MHz to 925MHz. The maximum read speed is 1000tags/s, minimum tag speed is 660ft/min. The power is +30dBm. The antenna selected in this RFID solution is CSL-771 which type is circular polarization.

B. Test task and Test process

According to the description of the intelligent product line, we build a test task. The test process is listed as below:

1) Validate the performance of RFID tags

Two kinds of tags are included in the bottle lids of wine. Some parameters are listed in Table 1.

<table>
<thead>
<tr>
<th>TABLE I. TEST RESULTS OF TAGS INCLUDED IN BOTTLE LIDS</th>
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<tbody>
<tr>
<td><strong>Indexes</strong></td>
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<tr>
<td>---------------------------</td>
</tr>
<tr>
<td>Frequency</td>
</tr>
<tr>
<td>920-925MHz</td>
</tr>
<tr>
<td>Communication protocol</td>
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<tr>
<td>Data storage capacity</td>
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<tr>
<td>Tag with TID</td>
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<td>Modulation system</td>
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</table>

In the test task, the write condition and performance are tested using the testing system. The test content includes input power, write and read range, etc.

2) The factors to influence the write and read performance of RFID on the intelligent product line

In the Fig.4, the RFID reader control two antennas, the one is writer antenna, and another is reader one. The task is to test the factors to influence performance of the RFID reader and two antennas.

C. Test results

1) Results of validate the performance of RFID tags

On the intelligent product line (see Fig. 5), the test is made to validate the performance of RFID tags included in bottle lids of wine.

The input power of two kinds of tags is test through change the power of RFID reader from -10dB to +30 dB. The read and write range is tested using an automatic control facility which can change the distance between antenna and tags automatically. The results are listed in Table 1.

<table>
<thead>
<tr>
<th>TABLE II. TEST RESULTS OF TAGS INCLUDED IN BOTTLE LIDS</th>
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<tr>
<td><strong>Indexes</strong></td>
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<tr>
<td>---------------------------</td>
</tr>
<tr>
<td>Lowest input power</td>
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<td>Read range (Fixed Reader)</td>
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<td></td>
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<tr>
<td>Write range (Fixed Reader)</td>
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</table>
2) Test the influence factors for RFID application

We use 80 bottles with Inlay Api tags and 80 bottles with Inlay Apr tags in the test. The test number is 8. 10 bottles are used in each test. Toward the first antenna, the write antenna, there are 77 Inlay Api tags written success, and there are 75 Inlay Apr tags written success. The success rates are 96.25% and 93.75%, respectively. For the validation antenna, the second one, there are 76 bottles (success rate 95%) with Inlay Api tags that pass RFID data validation, and there are 80 bottles with Inlay Apr tags pass the validation successful.

3) RFID performance under different speed

The speed of product line is an important factor for RFID application. We test the success rate of write and read. The speed range is from 200mm/s to 500mm/s where the step is 50mm/s. The test results are listed in Fig. 7. The speed rate s of RFID decreases when the speed is more than 350mm/s. It denote that the RFID application in product line

![RFID read and write success rate with different speed](image)

IV. CONCLUSION

Radio frequency identification applications on different industries are increasing in number. However, there is always some RFID solution that couldn’t be success implemented. Recently, the test techniques about RFID application have become hot research point. The proposed framework of testing system has following merits for evaluation of RFID application.

(i) The framework is flexibility which could be reconstructed according to the RFID solution. Meanwhile, the interfaces of automatics control, RFID readers are also flexibility.

(ii) The test task can be implemented automatically. The data of RFID tags, environments are automatic collected, and are analyzed.

(iii) The testing system can provide optimization strategies through change RFID solution parameters by automatics control facilities.

Since highly available, self-managing, and adaptable evaluation systems represent the future direction for developing and testing practically more useful RFID applications, we shall make efforts in our future work to use ecosystem-inspired mechanisms [10-12] to improve the flexibility of the system presented in this paper.

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