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Bidirectional Transformation Equipment for Agro-food Traceable Identification Labels

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Abstract: Bar code and RFID have become an important means of product identification in traceability system. Rapid conversion between different identifications plays a fundamental role in traceability link seamlessly. Based on identification feature analysis of the existing traceability systems, a bidirectional transformation equipment for traceable identification labels was designed and developed, which integrated industrial controller, RFID reader module, embedded barcode code printing module and barcode scanning module. The dynamic encryption technology was developed for the RFID to barcode conversion process, and the control flow procedure of RFID to barcode conversion was constructed. The hardware was implemented with the equipment function of label identification, bidirectional conversion, label printing and state monitoring. Two groups transformation test of RFID to 2D barcode and 2D barcode to RFID was divided. The frequency of RFID tag was 13.56 MHz, and QR code was used as 2D barcode. Totally 16 combinations of each group were performed in terms of different conversion quantities and contents. The result showed that the conversion success rate was 100% in the process from RFID to 2D barcode and the conversion success rate had a downward trend with the increase of quantity and content in the process from barcode to RFID. The downward trend was caused by RFID capacity limitation or section matching. In the two kinds of conversion mode, the conversion consumption time was increased with the increase of quantity and content. The conversion time was mainly consumed in reading and printing procedure. The equipment can satisfy the requirement of label tracking and information recording in identification method transformation process.

Key words: agro-food; traceability; identification labels transformation; 2D barcode; RFID

0 Introduction

Product identification with traceability information is the foundation of the agricultural products traceability system[1-3]. Different identification technology has different characteristics, and barcode identification is used widely and its cost is lowest[4-5]. Compared with the one-dimensional barcode, two dimensional barcode has such features as high density of stored information, large capacity, powerful error correction capability, resist stained and powerful distortion ability[6-8]. Barcode is read using artificial method within a close range and it is unable to access to large quantities of information in real time, so a non-contact automatic identification technology, RFID, rise in the 1990s[9-11].

There are many differences inpackaging way and value among agricultural products. The identification of agricultural products by different identification methods is an important means to trace the connection of information flow and real logistics in system construction[12-14]. FRITSCHLE et al.[15] uses a combination of one-dimensional and two-dimensional barcodes to trace poultry products. AMPATZIDIS et al.[16] uses bar codes and RFID to improve traceability in the manual harvesting process. QIAN et al.[17] integrated the use of bar code and RFID technology to build the quality of flour processing safety traceability system, and has carried on the system application testing. Zhou et al.[18] designed an agricultural product origin anti-counterfeit label packaging system using the comprehensive application of RFID authentication technology, two-dimensional code

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encryption technology and GPS anti-counterfeiting technology, which can integrate and seal agricultural products labeling and improve the efficiency of agricultural product packaging and labeling of authenticity.

Packaging unit aggregation and separation in agricultural products logistics is a common phenomenon, which has led to mismatch between the product flow and information, so that it will result in retracement chain. QIAN et al.[19] designed the portable circulation information gathering system and the promotion vegetable enterprise management system by using the barcode and RFID to identify the different packaging unit. The system improved the logistics retrospective precision. However, in this method, the barcode was scanned and printed manually, which has a risk that the barcode is not accurately matched with the RFID tag. So a bidirectional transformation equipment for agricultural products traceable identification, barcode and RFID information transformation was designed to realize the barcode reading, RFID printing, information matching, and other functions in this paper.

1 Overview of proposed framework

In existing agro-products traceability systems, most of the small package products are identified by barcode, which can meet the traceability demand, and also reduce costs. However, in large package, it need to quickly and accurately record the logistics process information, so it is best to use RFID for identification. This identification program in the product logistics (such as enter or exit the warehouse) can be deployed and record information through the RFID reader. Because of the more high relative value of large packaging products, the cost of RFID will not become a limit factor. Establishing the connection of the identification level and data level is the key to solve the information lost problem during the traceability logistics due to the aggregation and separation of the agricultural product package. For small package to large one, it focuses on the relationship establishment from barcode to RFID TID (Tag ID). TID is the only identification number of RFID label. The relationship between barcode and RFID is $n:1$, where n is the number of barcode labels. In the data level, the packaging time and operator information should be stored into the database for traceability. For the separation from large package to small ones, in terms of product coding Association, the focus is to establish a large package of TID RFID and small package on the relationship between the bar code. The relationship between them is $1:n$. In terms of data connection, the resolution information must be deposited in the database.

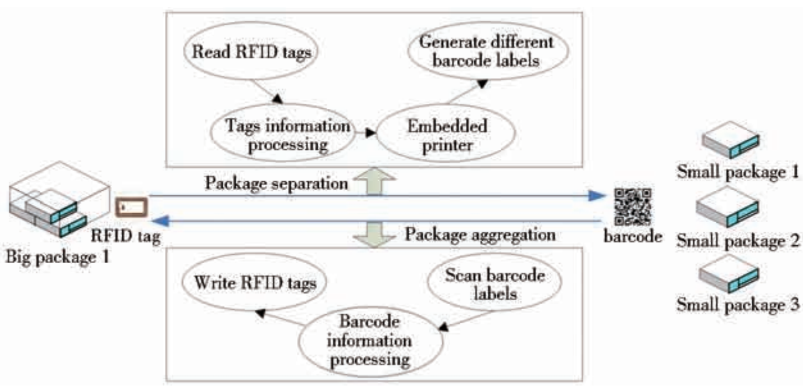

Fig. 1 Framework of traceable identification labels bidirectional transformation

As it is shown in Fig. 1, the bidirectional conversion between RFID and barcode labels consists of two unidirectional information flow: the conversion from the RFID identification information to the barcode identification information and the conversion from the bar code identification information to the RFID identification information. The former reads the RFID tag through the RFID reader and analyzes the information in the RFID tag through the RFID data processing module, then sends the extracted information to the embedded printing module, in the last according to different encoding rules, it will generate different number of barcode labels. The latter information flow is basically the opposite, first, it read some barcode labels, then the FID label will be written when the scanned number is equal to the set parameters, the information and the barcode quantity are stored into the RFID tag after the success of the card search.

2 Hardware design

Hardware design of bidirectional transformation equipment for agricultural product traceability identification includes touch industrial controller, RFID reader module, embedded printing module and bar code scanning module. The detail of each module is as follows:

(1) Touching industrial controller: a module from Beijing Novi Century Technology Co., Ltd. It is 7-inch industrial controller, and the OS kernel is Windows XP.

(2) RFID reader module: high-frequency and ultra-high frequency modules, and high frequency module from Intelligent Technology Co., Ltd. Chongqing Nuotasi LU3, ultra-high frequency from Shenzhen Sakamoto Technology Co., Ltd. 930MHz band D-300 UHF module.

(3) Embedded print module: Q8 printer (Bode Ltd. Shenzhen, China), which is able to print one-dimensional and two-dimensional bar code label.

(4) Barcode scanning module: select the NLS-EM3000 bar code reading engine of Newland Company to read all kinds of mainstream one-dimensional bar code and standard two-dimensional bar code.

Hardware structure is shown in Fig. 2.

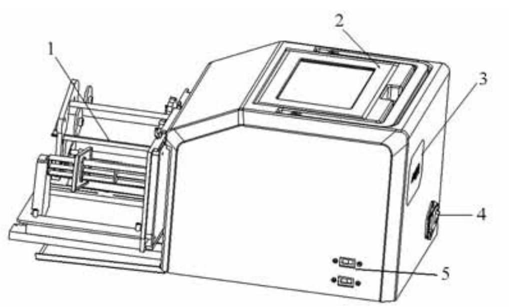

Fig. 2 Diagram of hardware module structure

1. Embedded printer 2. Industrial controller 3. RFID reader 4. Barcode scanner 5. Power switch

3 Function implementation

3.1 Two-dimensional barcode dynamic encryption in process from RFID to barcode information transformation

From the RFID to the bar code conversion, in order to achieve the conversion of two-dimensional bar code security features, two-dimensional barcodes are encrypted using the advanced encryption standard (AES)[20]. The core of the algorithm is to replace the S-box replacement, row shift, column mixing and round key of the encryption method in the AES algorithm. Here, we designed four steps, there are, change the trace code state matrix transposition, state matrix mixing and round key operation control, and to meet the requirements of direct encryption of decimal numbers. At the same time, in order to enhance the intensity of encryption and ensure the uniqueness of the generated trace back code, the same clear text is used to generate irregular ciphertext. The aim is to achieve "one key, once" result. Dynamic key tracking code is used to be chaotic random encryption. The encryption flowchart is shown in Fig. 3, where N_r is the number of rounds.

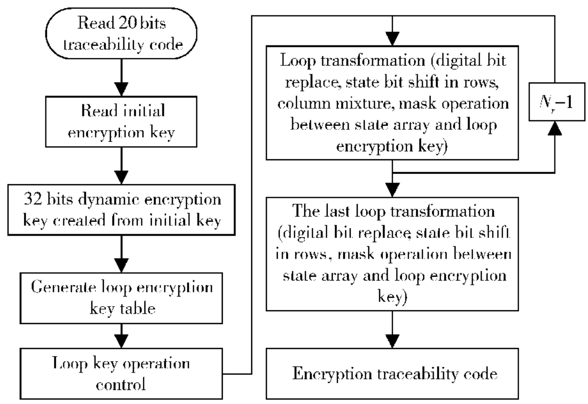

Fig. 3 Encryption flowchart of agro-food traceability code

Traceability code decryption operation is the inverse procedure of the above encryption operation. The main process includes digital bit replace, state matrix inverse shift and column mixing and status bits and round key modulo operation. The reverse bit of the traceable digit bit affects only one bit, while the state matrix inverse shift only affects the position of the decimal bit, and the positions of the inverse and inverse shift operations can be swapped. The key in the decryption process is the initial key acquisition, in the actual application process, you can use the USB key to distribute the key. Fig. 4 shows the flow of traceability code decryption algorithm.

3.2 Barcode - RFID conversion control procedure

In the conversion procedure from barcode to RFID, barcode number monitoring and counting is an important aspect. The whole flow is shown in Fig. 5.

The user first needs to set the number of barcode

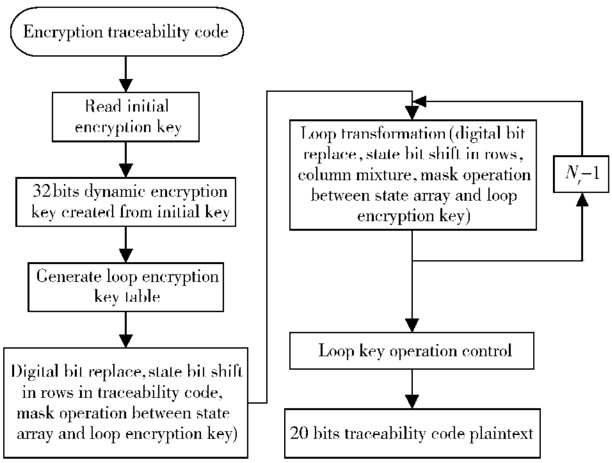

Fig. 4 Decryption flowchart of agro-food traceability code

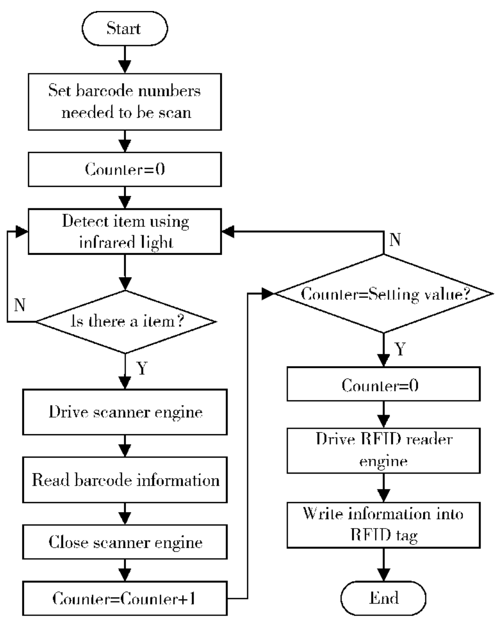

Fig. 5 Flowchart of transformation from barcode to RFID

which should be scanned, such as the number of small packages identified by the two-dimensional barcode for each large package identified by RFID tag. After this operation, the counter is reset to zero, and the barcode identification will be detected using infrared technology. Once the item is detected successfully, the barcode information will be read and write into the RFID tag, at the same time, the counter will be added with 1. After the scan is successful, close the bar code scanning header, thus saving energy consumption and improving the use of equipment time. When the number reaches the setting value, it indicates that the barcode needed for RFID conversion has reached the set number and the counter is cleared. The processor drives the RFID radio head and writes a specific number of barcode information into the RFID tag. And then it will go to the next process.

3.3 Core functions

Based on the industrial controller, The system is implemented based on Microsoft. NET platform by calling the module driver interface, mainly to achieve the following functions: ① RFID – barcode conversion: selecting the barcode type, RFD band, the number of conversion, the device automatically reads the RFID tag information, and print out the corresponding number of two-dimensional barcode. ② Bar code – RFID conversion: selecting the relevant settings and set the number, scan the relevant bar code, to reach the number of RFID tags written. ③ Condition monitoring: in the conversion process, real-time monitoring of the bar code reading and writing and RFID information, and read the wrong information to provide alarm function. System interface shown in Fig. 6.

4 Device test

4.1 Test method

The designed equipment was tested by multi-group solution. The agricultural products identification transformation equipment is shown in Fig. 7. Test consisted of two parts: RFID – barcode conversion and bar code – RFID conversion, respectively. The test conditions about the number of conditions and conversion is shown in Tab. 1, where conversion contents is the content in the conversion subject, the number of conversions refers to how many subjects are

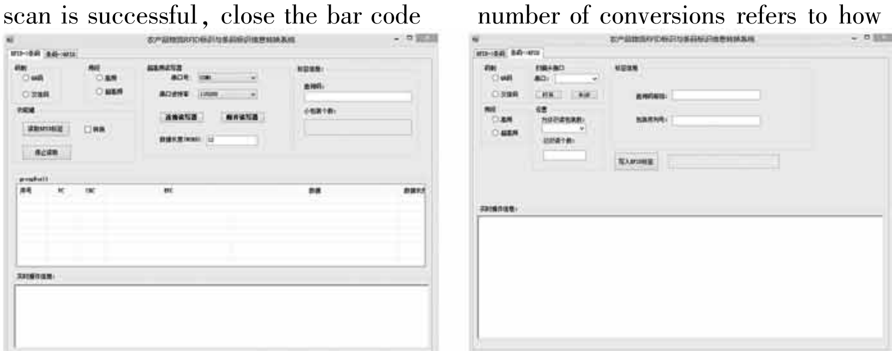

Fig. 6 System interfaces

converted to objects. Such as in the first row of Tab. 1, the "10-digit traceable code" is included in the RFID tag under the condition of "RFID – barcode", and one RFID tag is converted into five two-dimensional barcode labels. The RFIG tag used in the test is the S50 contactless IC card. The frequency is 13. 56 MHz, and the storage structure is 16 sectors. Each sector draws 4 blocks, each 16 bytes. In addition to curing the storage vendor code and control block, a total of 752 bytes can be stored, and two-dimensional barcode is QR code.

Fig. 7 Traceable identification labels bidirectional transformation equipment for agro-food

Tab. 1 Test condition setting

Conditions	Transformation content	Transformation number
RFID – barcode	10 bits traceability code(RB – C1)	1 – 5(RB – A1)
	10 bits traceability code + 10 characters(RB – C2)	1 – 10(RB – A2)
	10 bits traceability code + 20 characters(RB – C3)	1 – 15(RB – A3)
	10 bits traceability code + 30 characters(RB – C4)	1 – 20(RB – A4)
Barcode – RFID	10 bits traceability code(BR – C1)	5 – 1(BR – A1)
	10 bits traceability code + 10 characters(BR – C2)	10 – 1(BR – A2)
	10 bits traceability code + 20 characters(BR – C3)	15 – 1(BR – A3)
	10 bits traceability code + 25 characters(BR – C4)	20 – 1(BR – A4)

By combining the above test conditions, there are 16 combinations under each unidirectional conversion condition, and 32 combinations under 2 conversion conditions, and 5 tests in each combination. The test effect is measured by the conversion success rate R and the individual conversion time T, which is defined as

$$R_i = \frac{\sum_{j=1}^{5} M_{ij}}{5n} \times 100\% \tag{1}$$

$$T_i = \frac{\sum_{j=1}^{5} t_{ij}}{5} \tag{2}$$

where M_{ij} is the correct numbers of the j^{th} transformation in the i^{th} combination. n is transformation numbers in the i^{th} combination. R_i is average of 5 times transformation in the i^{th} combination. t_{ij} is time of the j^{th} transformation in the i^{th} combination. T_i is time average of 5 transformations in the i^{th} combination.

4.2 Test results analysis

The test results of RFID-barcode 16 combinations and bar code-RFD 16 combinations are shown in Tab. 2.

(1) Conversion success rate. In the conversion from RFID to barcode, the conversion success rate reached 100% under all 16 test conditions. The conversion number and conversion content has no effect on the success rate. In the conversion from barcode to RFID, regardless of the number of conversion content, the conversion success rate reached 100% in the conversion '5 – 1' and '10 – 1' conditions. In the conversion of '15 – 1' and '20 – 1', except the conversion content of 10-digit digital traceability code, the rest of the conditions of the conversion success rate decreased. In addition, with the conversion content increasing, conversion success rate is decreased, especially, when the conversion content are '10-digit traceability code +25 characters' and '20 – 1', the conversion success rate is less than 90% and 89%, respectively. This shows that the conversion of two-dimensional code to RFID, with the increase of conversion content and number, there will be unsuccessful conversion phenomenon. The main reason may be that the RFID capacity is close to the maximum, or conversion information which was stored in the boundary areas of RFID memory was not read correctly.

(2) Conversion time. In the conversion from RFID to the barcode, in general, the conversion time increases when the number of conversions increases. And the conversion content also will lead to an increase in conversion time. Conversion process time mainly costs in RFID tag read and barcode printing. For different conditions, RFID read time difference is not large, with the conversion content increasing, single

barcode label printing time will increase. The increase in the number of conversion will lead to the total conversion time increase. In the transition from barcode to RFID, there is a similar trend, but the total time overhead than RFID – barcode to be much more, mainly for barcode reading and FID write. When multiple tags of information were written into RFID, the barcode read time is accounted for a larger proportion.

Tab. 2 Test results of different conditions

RFID – barcode	R/%	T/s	barcode – RFID	R/%	T/s
RB – C1/RB – A1	100	2.1	BR – C1/BR – A1	100	10.4
RB – C1/RB – A2	100	2.7	BR – C1/BR – A2	100	18.9
RB – C1/RB – A3	100	3.1	BR – C1/BR – A3	100	27.6
RB – C1/RB – A4	100	4.1	BR – C1/BR – A4	100	35.7
RB – C2/RB – A1	100	2.2	BR – C2/BR – A1	100	12.2
RB – C2/RB – A2	100	2.7	BR – C2/BR – A2	100	22.9
RB – C2/RB – A3	100	3.3	BR – C2/BR – A3	97.3	32.1
RB – C2/RB – A4	100	4.5	BR – C2/BR – A4	96.0	42.3
RB – C3/RB – A1	100	2.2	BR – C3/BR – A1	100	12.9
RB – C3/RB – A2	100	2.8	BR – C3/BR – A2	100	23.4
RB – C3/RB – A3	100	3.9	BR – C3/BR – A3	100	34.1
RB – C3/RB – A4	100	5.3	BR – C3/BR – A4	94.0	43.5
RB – C4/RB – A1	100	3.2	BR – C4/BR – A1	100	13.6
RB – C4/RB – A2	100	4.0	BR – C4/BR – A2	100	24.7
RB – C4/RB – A3	100	5.1	BR – C4/BR – A3	93.3	36.1
RB – C4/RB – A4	100	5.6	BR – C4/BR – A4	89.0	45.2

5 Conclusions

In order to satisfy the requirements of barcode and RFID seamless transformation in agriculture products logistics, the paper designs a bi-directional conversion equipment of agricultural products which integrates industrial RFID reader module, embedded printing module and barcode scanning module. It realizes the label reading, bidirectional conversion, logo printing, status monitoring and other functions. The success rate of conversion and conversion time of the test achieved good results. In order to meet the packaging identification process and tracking requirements, it should improve the conversion success rate in actual application. First, it should focus on barcode – RFID reasonable conversion number and conversion content. On the other hand, it should further study the capacity judgment algorithm of RFID multi-sector read, such as single sector overflow control.

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农产品追溯标识双向转换设备研究

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摘要: 条码、RFID等已成为追溯系统中产品标识的重要手段,实现不同标识间的快速转换已成为追溯环节无缝衔接的基础。在分析现有追溯系统标识特点的基础上,设计了集成工业控制器、RFID读写模块、嵌入式打印模块、条码扫描模块的农产品追溯标识双向转换设备,突破了RFID-条码转换中的二维条码动态加密技术,构建了条码-RFID转换中的控制流程,实现了标识读取、双向转换、标识打印、状态监测等功能。利用设计的设备进行了不同转换内容和转换数量下的双向测试,结果表明在RFID-条码的转换中转换成功率均达到了100%;在条码-RFID的转换中随着转换数量的增加、转换内容的增多,转换成功率存在下降趋势。2种转换方式下,转换时间均随转换数量和转换内容增多存在增加趋势。设备可满足加工包装过程中不同包装载体标识跟踪与信息记录的需求。

关键词: 农产品; 追溯; 标识转换; 二维条码; RFID

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Abstract: Bar code and RFID have become an important means of product identification in traceability system. Rapid conversion between different identifications plays a fundamental role in traceability link seamlessly. Based on identification feature analysis of the existing traceability systems, a bidirectional transformation equipment for traceable identification labels was designed and developed, which integrated industrial controller, RFID reader module, embedded barcode code printing module and barcode scanning module. The dynamic encryption technology was developed for the RFID to barcode conversion process, and the control flow procedure of RFID to barcode conversion was constructed. The hardware was implemented with the equipment function of label identification, bidirectional conversion, label printing and state monitoring. Two groups transformation test of RFID to 2D barcode and 2D barcode to RFID was divided. The frequency of RFID tag was 13.56 MHz, and QR code was used as 2D barcode. Totally 16 combinations of each group were performed in terms of different conversion quantities and contents. The result showed that the conversion success rate was 100% in the process from RFID to 2D barcode and the conversion success rate had a downward trend with the increase of quantity and content in the process from barcode to RFID. The downward trend was caused by RFID capacity limitation or section matching. In the two kinds of conversion mode, the conversion consumption time was increased with the increase of quantity and content. The conversion time was mainly consumed in reading and printing procedure. The equipment can satisfy the requirement of label tracking and information recording in identification method transformation process.

Key words: agro-food; traceability; identification labels transformation; 2D barcode; RFID

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引言

带追溯信息的产品标识是实现农产品追溯系统的基础[1-3]。不同标识技术具有不同的特点,其中条码标识应用广泛,成本较低[4-5]。与一维条码相比,二维条码具有存储信息密度高、容量大、纠错能力强、抗污损和畸变能力强等特点[6-8]。由于条码技术只能采用人工的方法进行近距离的读取,无法实时快速获取大批量的信息,因此一种非接触式自动识别技术——射频识别(RFID)技术在20世纪90年代兴起[9-11]。

农产品在包装方式、产品价值等方面存在着较大差异,采用不同的标识方式对农产品进行标识是追溯系统构建中信息流与实物流关联的重要手段[12-14]。FRSCHLE等[15]采用一维和二维条码相结合的方式对禽类产品进行了追溯标识;AMPATZIDIS等[16]在果品手动采收过程中应用条码和RFID提高了追溯效率;QIAN等[17]综合采用条码和RFID技术构建了面粉加工过程质量安全追溯系统,并进行了系统应用测试;周超等[18]通过综合应用RFID身份认证技术、二维码加密技术、GPS防伪技术,设计了一种可以对农产品封箱贴标一体化、含动态防伪标识的农产品原产地防伪标识包装系统,提高了农产品包装的生产效率和标识的真实性。

不同包装单元的聚合与拆分是农产品流通中的普遍现象,这一现象已导致产品流与信息流不匹配,从而使追溯断链。钱建平等[19]采用条码和RFID分别对不同包装单元进行标识,设计了便携式流通信息采集系统并升级蔬菜企业管理系统,提高了流通过程追溯精度。但该方法中采用人工扫描条码然后打印并贴制RFID标签的方法,存在着条码与RFID匹配不准确的风险,也存在着大量使用人力的问题,因此本文设计一种农产品追溯标识双向转换设备,实现条码与RFID标识转换中的条码读取、RFID打印、信息匹配等功能。

1　总体框架

在现有的农产品追溯系统中,大部分小包装产品以条码进行标识,这样既可满足追溯需求,也能降低成本。而在大包装中,由于需要快速、准确地记录物流过程信息,因此最好采用RFID进行标识,这种标识方案在产品进入物流环节时(如出入库)可通过部署RFID读写器便捷地记录出入库信息,且由于大包装产品相对价值较高,因此RFID的成本也不会成为其限制因素。建立标识层面的关联和数据层面的衔接是解决农产品包装的聚合和拆分中追溯断链的关键。对于从小包装到大包装的聚合,在产品标识关联方面,重点是建立小包装的条码与大包装的RFID TID(Tag ID)的关联,TID是RFID标签的唯一编号,它们之间的关系是多对1;在数据衔接方面,需将包装聚合时间、操作人员等信息存入数据库中,以便追溯。对于从大包装到小包装的拆分,在产品编码关联方面,重点是建立大包装的RFID TID与小包装上条码的关联,它们之间的关系是1对多;在数据衔接方面,需将拆分信息存入数据库中。

如图1所示,RFID与条码的双向转换主要包括2个单向信息流:从RFID标识信息到条码标识信息的转换和从条码标识信息到RFID标识信息的转换。前者通过RFID扫描头识读电子标签,然后通过RFID数据处理模块分析RFID标签中的信息,将提取的信息发送至嵌入式打印机模块,并根据不同的编码规则和所需生成的条码数量生成条码标识;后者信息流基本相反,首先需要设定读取条码标签的个数,通过扫描头扫描条码,当数量等于设定的参数时,系统提示当前扫描条码标签个数已达要求,进行RFID标签写入,通过组合条码标签的共有信息后,将信息与条码数量在寻卡成功后写入RFID电子标签中。

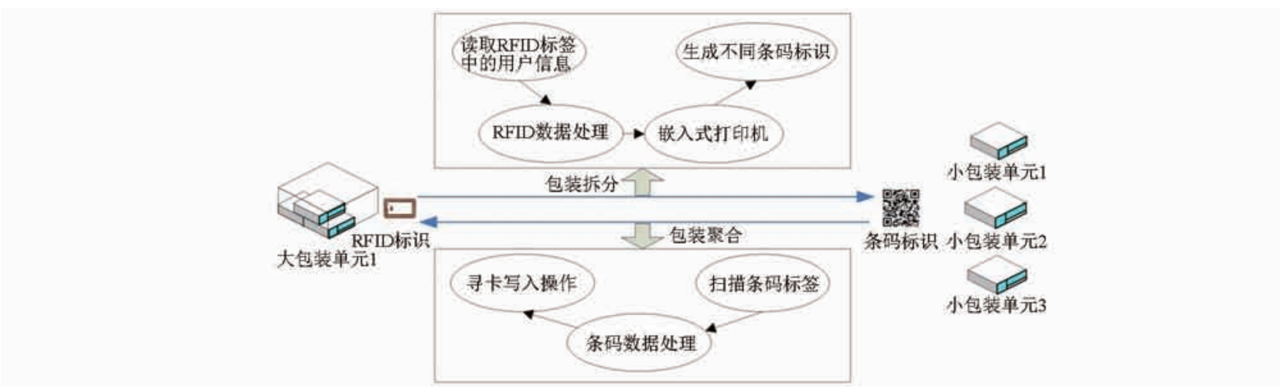

图1　标识转换架构图

Fig. 1　Framework of traceable identification labels bidirectional transformation

2　硬件设计

农产品追溯标识双向转换设备硬件设计主要包括触摸工业控制器、RFID 读写模块、嵌入式打印模块和条码扫描模块，利用控制器对各模块进行双向的交互控制。各模块选型如下：

（1）触模工业控制器：采用北京诺维世纪科技有限公司的 7 寸工业控制器，内核采用 Windows 系统。

（2）RFID 读写模块：采用高频和超高频 2 种模块，高频采用重庆诺塔斯智能科技有限公司的 LU－3，超高频采用深圳深坂科技有限公司的 930 MHz 频段 D－300 型超高频模块。

（3）嵌入式打印模块：选用深圳博思得公司的 Q8 型打印机，能够打印一维和二维条码标签。

（4）条码扫描模块：选用新大陆公司的 NLS－EM3000 型条码识读引擎，识读各类主流一维条码和标准二维条码。

具体的硬件结构图如图 2 所示。

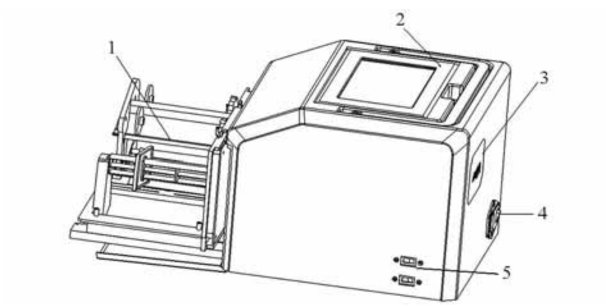

图 2　硬件模块组成图

Fig. 2　Diagram of hardware module structure

1. 嵌入式打印模块　2. 触模工业控制器　3. RFID 读写模块　4. 条码扫描模块　5. 电源开关

3　功能实现

3.1　RFID－条码转换中的二维条码动态加密

从 RFID 到条码的转换中，为了实现转换出二维条码的防伪性能，基于课题组前期的研究成果[20]，采用改进高级加密标准（Advanced encryption standard，AES）对二维条码进行加密。其核心是将 AES 算法中加密轮变换的 S 盒替换、行移位、列混合和轮密钥，设计为追溯码状态位替换、状态矩阵行移位、状态矩阵列混合和轮密钥运算控制 4 个步骤，以适应十进制数直接加密的要求。同时为增强加密强度，保证生成追溯码的唯一性，使同一明文生成无规律的密文，实现“一次一密”防伪效果，采用动态密钥对追溯码进行混沌随机加密。具体加密流程如图 3 所示，其中 N_r 为变换轮数。

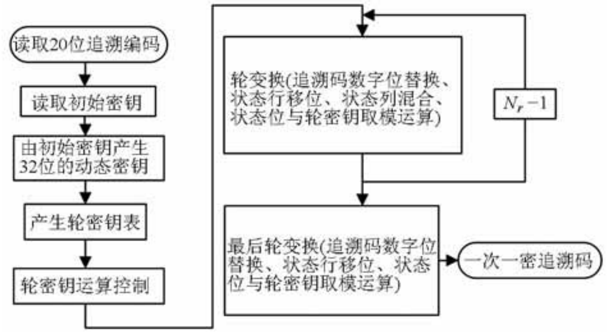

图 3　追溯码加密流程

Fig. 3　Encryption flowchart of agro-food traceability code

追溯码解密运算是上述加密运算的逆过程。主要过程包括数字位反置换、状态矩阵反行移位和反列混合、状态位与轮密钥取模运算等。追溯码数字位的反置换只影响一个进制位，而状态矩阵反移位操作只影响十进制位的位置，可以交换反置换和反移位操作的位置。解密过程中的关键是初始密钥的获取，在实际应用过程中可以通过 USBKey 的方式进行密钥的发配。追溯码解密算法的流程如图 4 所示。

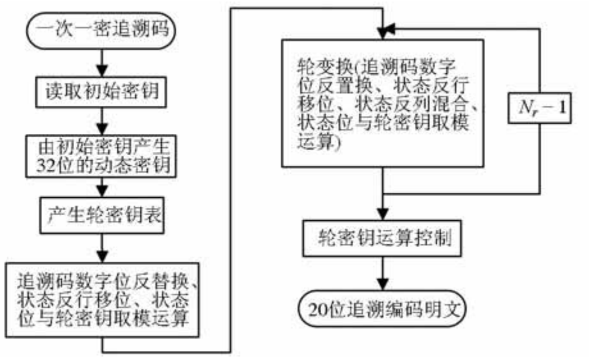

图 4　追溯码解密流程

Fig. 4　Decryption flowchart of agro-food traceability code

3.2　条码－RFID 转换中的控制流程

从条码到 RFID 的转换中，根据需要转换的条码数量进行流程控制是重要内容，其流程如图 5 所示。用户首先需要设置条码扫描的个数，如每个用 RFID 标识的大包装规定容纳的用二维条码标识的小包装数量；当用户设置完数量后，处理器对计数器清零，为后续计数做准备；红外开始探测贴有二维条码的物品，当物品到来时，驱动条码扫描激光头，对经过激光头射线区域内的条码标识进行扫描；扫码成功后，关闭条码扫描激光头，从而节约能耗，提高设备的使用时间；扫码的同时进行计数，未到设置数量时，继续进行包装监测与识读；当数量达到设置的数字时，表示 RFID 所需转换的条码已达到所设定数量，计数器清零，处理器驱动 RFID 射频头，将特定数量的条码信息写入到 RFID 标识中，到此一个流程完毕，进入下一个流程。

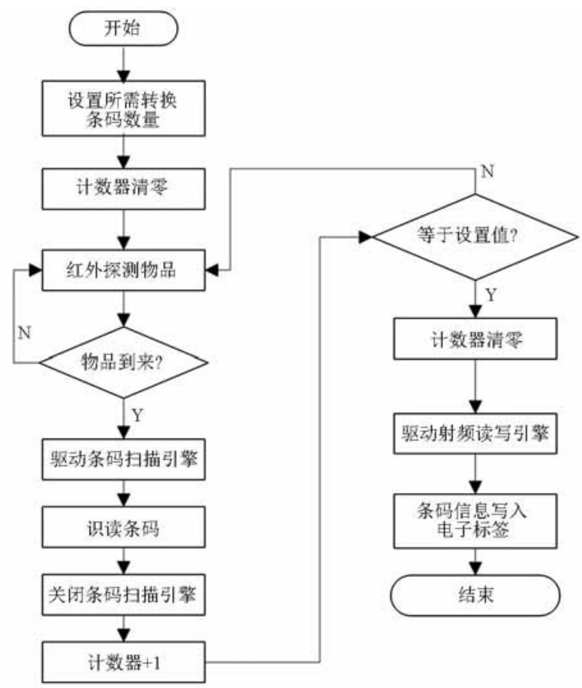

图5 条码标识至RFID标识转换流程

Fig. 5 Flowchart of transformation from barcode to RFID

3.3 核心功能

基于工业控制器,通过调用各模块驱动接口,采用Microsoft. NET开发工具,主要实现如下功能:①RFID-条码转换:选择条码码制、RFID频段、转换数量后,设备自动读取RFID标签信息,并打印出对应数量的二维条码。②条码-RFID转换:选择相关设置及设定数量后,扫描相关条码,达到数量后写入RFID标签。③状态监测:在转换过程中,实时监测读写的条码及RFID信息等,并对读取有误的信息提供报警功能。系统界面如图6所示。

4 设备测试

4.1 测试方法

采用设计的农产品追溯标识转换设备进行分组测试,设备实物如图7所示。测试分RFID-条码转换和条码-RFID转换两部分,分别设置所含内容条件和转换数量条件如表1所示,其中转换内容是指转换主体中所含内容,转换数量是指多少主体转换为多少客体。如表1中的第1行表示在“RFID-条码”的条件下,RFID中包含“10位数字追溯码”内容,1个RFID标签转换为5个二维条码标签。测试中所用标签为S50非接触式IC卡,其工作频率为13.56 MHz,存储结构为16个扇区、每个扇区有4块、每块16字节,除固化存储厂商代码及控制块外,共可存储752字节;二维条码为QR码。

图6 系统界面

Fig. 6 System interfaces

图7 农产品追溯标识转换设备实物

Fig. 7 Traceable identification labels bidirectional transformation equipment for agro-food

表1 测试条件设置

Tab. 1 Test condition setting

条件	转换内容	转换数量
RFID-条码	10位数字追溯码(RB-C1)	1-5(RB-A1)
	10位数字追溯码+10个字母(RB-C2)	1-10(RB-A2)
	10位数字追溯码+20个字母(RB-C3)	1-15(RB-A3)
	10位数字追溯码+30个字母(RB-C4)	1-20(RB-A4)
条码-RFID	10位数字追溯码(BR-C1)	5-1(BR-A1)
	10位数字追溯码+10个字母(BR-C2)	10-1(BR-A2)
	10位数字追溯码+20个字母(BR-C3)	15-1(BR-A3)
	10位数字追溯码+25个字母(BR-C4)	20-1(BR-A4)

注:RB为RFID到条码的转换,BR为条码到RFID的转换;C1、C2、C3、C4分别代表不同转换内容;A1、A2、A3、A4分别代表不同转换数量。

通过将上述测试条件进行两两组合,每个单向转换条件下有16种组合,2个转换条件共有32种组合,每个组合进行5次测试。用转换成功率 R 和

单个转换时间 T 来衡量测试效果，其定义为

$$R_i = \frac{\sum_{j=1}^{5} M_{ij}}{5n} \times 100\% \qquad (1)$$

$$T_i = \frac{\sum_{j=1}^{5} t_{ij}}{5} \qquad (2)$$

式中　M_{ij}——第 i 个组合中第 j 次转换正确的个数，正确转换是指主体中的所有信息均能转换到客体中

n——第 i 个组合中的转换数量

R_i——第 i 个组合中 5 次测试转换成功率的平均值

t_{ij}——第 i 个组合中第 j 次转换所用时间

T_i——第 i 个组合中 5 次测试所消耗时间的平均值

4.2　转换测试结果分析

RFID－条码 16 种组合和条码－RFID 16 种组合下的测试结果如表 2 所示。

表 2　不同条件下的测试结果

Tab. 2　Test results of different conditions

RFID－条码转换条件	转换成功率 R/%	转换时间 T/s	条码－RFID 转换条件	转换成功率 R/%	转换时间 T/s
RB－C1/RB－A1	100	2.1	BR－C1/BR－A1	100	10.4
RB－C1/RB－A2	100	2.7	BR－C1/BR－A2	100	18.9
RB－C1/RB－A3	100	3.1	BR－C1/BR－A3	100	27.6
RB－C1/RB－A4	100	4.1	BR－C1/BR－A4	100	35.7
RB－C2/RB－A1	100	2.2	BR－C2/BR－A1	100	12.2
RB－C2/RB－A2	100	2.7	BR－C2/BR－A2	100	22.9
RB－C2/RB－A3	100	3.3	BR－C2/BR－A3	97.3	32.1
RB－C2/RB－A4	100	4.5	BR－C2/BR－A4	96.0	42.3
RB－C3/RB－A1	100	2.2	BR－C3/BR－A1	100	12.9
RB－C3/RB－A2	100	2.8	BR－C3/BR－A2	100	23.4
RB－C3/RB－A3	100	3.9	BR－C3/BR－A3	100	34.1
RB－C3/RB－A4	100	5.3	BR－C3/BR－A4	94.0	43.5
RB－C4/RB－A1	100	3.2	BR－C4/BR－A1	100	13.6
RB－C4/RB－A2	100	4.0	BR－C4/BR－A2	100	24.7
RB－C4/RB－A3	100	5.1	BR－C4/BR－A3	93.3	36.1
RB－C4/RB－A4	100	5.6	BR－C4/BR－A4	89.0	45.2

（1）转换成功率

在从 RFID 到条码的转换中，所有 16 种测试条件下，其转换成功率均达到了 100%，转换数量和转换内容对成功率没有影响。在从条码到 RFID 的转换中，当转换数量为“5－1”和“10－1”的条件，无论转换内容有多少，其转换成功率均达到了 100%；当转换数量为“15－1”和“20－1”时，除转换内容为“10 位数字追溯码”外，其余条件均出现了转换成功率下降的情况，而且有随转换内容增加，转换成功率呈下降的趋势；尤其是当转换内容为“10 位数字追溯码＋25 个字母”和转换数量为“20－1”的条件下，其转换成功率低于 90%，为 89.0%。由此可见，二维码到 RFID 的转换，随着转换内容增多和转换数量增加，会出现转换不成功的现象，其主要原因可能是 RFID 容量接近上限，或转换时信息存储在 RFID 的扇区分区处导致不能正确识读。

（2）转换时间

在从 RFID 到条码的转换中，总体来说，转换时间有随转换数量增加而增加的趋势，同时，转换内容的增多也会导致转换时间的增加；在转换过程中时间主要消耗在 RFID 读取、条码打印上，对于不同条件，RFID 的读取时间差异不大，随着转换内容增加，单张条码标签打印时间会有所增加，但增加不多，而转换数量的增加会导致总转换时间增加。在从条码到 RFID 的转换中，也存在相似的趋势，但其总时间开销比 RFID－条码要多很多，主要用于条码读取和 RFID 写入，当多个标签信息写入 RFID 时，条码读取的时间占比重较大。

5　结束语

针对农产品追溯系统中条码、RFID 等不同标识方式无缝转换的需求，设计了集成工业控制器、RFID 读写模块、嵌入式打印模块、条码扫描模块的农产品追溯标识双向转换设备，实现了标识读取、双向转换、标识打印、状态监测等功能；并进行了转换成功率和转换时间的测试，取得了较好的测试效果。设备可满足加工包装过程中不同包装载体标识跟踪与信息记录的需求，实际应用中为提高转换成功率，一方面应重点考虑条码－RFID 转换的合理转换数量和转换内容，另一方面，应进一步研究 RFID 多扇区读取的容量判断算法，对单个扇区进行溢出控制。

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