Food Information Traceability for the Supply Chain of Online Ordering Platform Based on Commercial IoT

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Research Article

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Abstract: As more and more people pay attention to food safety, the research on food traceability is becoming popular. The information traceability of the food supply chain is made more difficult by the fact that the online shopping platform comprises not only a big number of merchants, but also a high number of users, raising the chance of misunderstanding between different parties. To ensure food safety, this article proposes and analyzes a commercial IoT-based food supply chain information traceability system. Users need just to scan the traceability source code with the APP device to acquire information about the food's origin, processing, and merchants. They can also order uniform food ingredients for dispersed small merchants to assure food safety. The developed system consists of two components: a purchase system for food and a processing system for food. A database connects the two systems, and they are then incorporated into the food traceability system. The numerical results reveal that our proposed system has a more than 90% accuracy rate for source code traceability as well as a satisfying performance robustness with a large number of concurrently logged-in users.

Keywords: Commercial Internet of Things, RFID Technology, Shopping Platform, Food Information Traceability

1. Introduction

With the rise of online food shopping platforms, more and more young people order food online, and its convenience has successfully captured the hearts of young people. However, news of unsanitary food delivery from time to time also makes people more worried about food safety issues. With the evolution of the supply chain of food, especially agricultural products, from a traditional model to a modern model, and in recent years, China has strengthened the construction of channels for agricultural product supply chains and policies and investments to ensure the safety of agricultural products. Specialized supermarkets for agricultural products and specialty foods continue to emerge. The traditional large supermarket retail industry has also set up a special area for fresh produce, and residents' food consumption has gradually shifted from the farmer's market to the supermarket. The emergence of the integration trend of the food supply chain has made the supermarkets of production and processing enterprises in planting and breeding bases gradually become the main food supply mode supporting this safe supply chain. The continuous occurrence of vicious food safety incidents has caused consumers to worry about food safety, causing people to panic about food safety. As much as 65.7% of the public ranks food safety as the worst part of social life. People realized the importance of anti-counterfeiting traceability of food, and began to research and construct anti-counterfeiting traceability system, in order to build a traceability system that can ensure that the food that people get is healthy and safe.

Thanks to the successful precedents in developed countries, although China's anti-counterfeiting traceability started later than others, it has also achieved convincing achievement. With the maturity of the food traceability system, China has also formulated corresponding laws and regulations to maintain the safety of food circulating on the market. At the beginning of this century, as a pioneer in food safety traceability, barcode engineering was widely used in food traceability systems. Food safety issues have also seriously affected the export of Chinese food. Other countries have extended the ban on milk and dairy products in China, resulting in a sharp drop in the export delivery value of the dairy industry. These situations all show that China's food safety problems are becoming increasingly serious. Therefore, it is very meaningful to strengthen the tracking and tracing of food, ensure the safety of the farm-to-table food supply chain, and improve the quality of life of the Chinese people.

There are many studies on the new concept of the Internet of Things. For example, Delsing J et al. discussed the transition from the traditional automation technology defined by ISA-95 to the highly distributed Internet of Things (IoT) and SoS-based automation. These automation systems make full use of Internet technology, thus realizing the Industry 4.0 and RAMI 4.0 models [1]. Lu Y and others believe that the Internet of Things is a new technology paradigm designed to connect anyone anytime, anywhere, thereby generating innovative new applications and services. They systematically reviewed the business literature related to the Internet of Things and critically explained the latest development status [2]. Rocha C believes that the Internet of Things (IoT) still dominates the paradigm that focuses more on tangible things and physical devices, and less on management and business environments, and lacks research that clarifies how the Internet of Things can help corporate management create perceived value for companies. They proposed a framework called the Internet of Management (IoMA) to understand how the IoT ecosystem supports management decisions [3]. Wv A and others pay special attention to exploring how BCT and the Internet of Things can benefit from business model innovation. The purpose of their research is to understand how to use BCT in the IoT environment to create the latest technology of a secure decentralized architecture. They believe that the Internet of Things is not secure by design, making its applications particularly vulnerable to security and privacy threats, which hinders the large-scale proliferation of Internet of Things applications. With BCT capabilities, BCT can be used as an indispensable part to solve many deficiencies in IoT applications. Therefore, existing businesses can be improved and new business models can be brought into reality. Eliminating the need for third parties to ensure the trust of commercial transactions is of great value for commercial innovation in many fields, such as digital supply chains, vehicle systems, monitoring systems, and the creation of new business models [4]. Noori-Daryan M and others have established two scenarios of economic production quantity models in a three-level supply chain composed of suppliers, manufacturers, and wholesalers. The main goal of their research is to maximize the total profit of the chain by optimizing the number of orders from suppliers and the sales prices of manufacturers and wholesalers, consider the Nash equilibrium method among chain members. Finally, numerical examples are used to illustrate the applicability of the introduced model and compare the on-chain profits in the two scenarios [5]. From the existing literature, Raak N et al. identified and discussed three main areas of food waste: product deterioration and corruption during logistics operations, by-products of food processing, and consumers' perceptions of quality and safety [6]. Beitzen-Heineke E F and others believe that social benefits include the support of small farmers, greater transparency in the supply chain, and consumers' right to know. However, due to the slower shopping operation and limited product types, these benefits are at the expense of consumer convenience [7]. Nyamah E Y et al. used a structured questionnaire to collect cross-sectional survey data in order to examine the key risk components (probabilities and consequences) that affect the operations of Ghana's agri-food supply chain and their respective thresholds. The risk thresholds related to the agri-food supply chain are classified using the risk matrix scale and classification described in the Project Management Knowledge System (Project Management Association, 2013). Their experimental results show that risks are inevitable in the agricultural food chain, but they pose different threats to the chain operation [8]. Although there is sufficient research on the Internet of Things, the domestic research on food information traceability systems is still at a relatively preliminary stage, and there is no unified standard for some parameters and references of the system.

Other than the existing work, this paper has the following innovations for the food traceability system. First, the RFID IoT technology has been studied intensively, and the application of RFID technology to the food traceability platform has been fully analyzed. Using its identification technology, the source of food can be traced back better. Second, the analysis of the food traceability system is develop specifically for online shopping platform. The current rise of online shopping platforms, due to its chaotic nature, the large number of merchants and customers, the variety of food, and the uneven quality of food, are very difficult to trace. This work studies its difficulties, hoping to find a way to trace its origin. Finally, we present the numerical results to justify the reliability and efficiency of our design.

2. Basics of IoT Technologies

2.1 Development of the Internet of Things

The Internet of Things is an advanced network form based on the Internet. The main differences between the Internet and the Internet of Things are: the Internet of Things realizes the connection between things and people or things and things. The Internet of Things uses RFID technology, two-dimensional code technology, GPS technology, sensor technology, wireless sensor network and other technical means to collect and obtain information on objects anytime and anywhere [9]. The Internet of Things is a comprehensive application of various sensing technologies, and the application of sensors is the basis for the construction of the Internet of Things. Various sensors collect all kinds of information at a certain frequency according to the needs of the system, and the information collected is real-time and accurate data [10]. Sensors are the providers of information sources. According to the requirements of the system, the IoT system needs to deploy a large number of sensors [11].

2.2 RFID Barcode Traceability Technology

RFID technology was first developed in the military field, and the most important reference is how to distinguish between enemy and our aircraft [12]. In the 1960s, people began to explore the application of RFID technology to other fields, where it only prevents the identified target from being stolen, and cannot distinguish the difference between the identified objects. In the 1970s, scholars, companies, and governments in various fields began to actively research and develop RFID technology to tap its economic value. In the 1980s, RFID technology was perfected and began to be applied to different fields. Special industrial markets in Europe first used it to track and locate products that cannot use barcode technology. In United States RFID is mainly used in the transportation industry and access control; in Norway, the electronic toll collection system has been applied, and very good results have been obtained. As a matter of fact, smart RFID powered by artificial intelligence begins to spread around the world [13-15].

3. Methods

3.1Tracing Technology

The key part of food traceability is the final traceability source code, which is very critical for its identification. In this system, the case of scanning motion codes is discussed. That is to say, people take pictures of the source code during exercise, and then upload the system to recognize it. This is the video processing technology used. Below shows the tracing technology and realization of video processing.

We know that each video can be split into a single frame, and its detection is also based on the number of frames to identify and scan. As shown in Figure 1, the R() on both sides represent different reference positions, which are also pixels that need to be predicted. The P() inside represents the pixels in the picture.

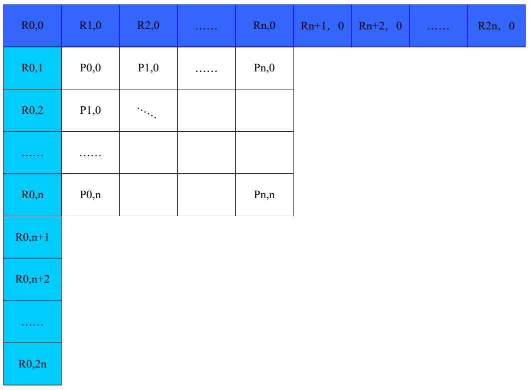

Figure 1 Adjacent reference pixel position template

Figure 2 shows the prediction directions of 33 angles. For intra-frame prediction, the position of the prediction point is at an uncertain angle. If want a better prediction to succeed, it need to determine the angle.

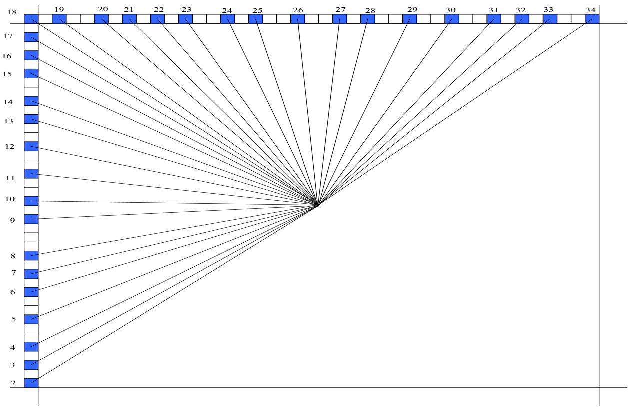

Figure 2 33 kinds of angle prediction direction

Figure 2 shows the prediction directions of 33 angles, but in fact there are 35 prediction modes, and 0 represents the Planar mode, and 1 represents the DC mode. The following describes the reference pixel calculation method.

(1) Planar mode

The reference pixel calculation method is as follows, where: a represents the horizontal direction, b represents the vertical direction, and S represents the size of the transform block, then the pixel value is expressed as formula 1:

$$pred[a][b] >> (\log_2(S)+1); a,b \in [0, S-1] \tag{1}$$

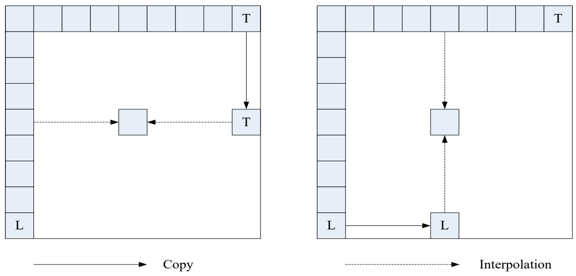

Figure 3 Schematic diagram of pixel predicted values in Planar mode

As shown in Figure 3, the pixels are being copied and interpolated, which is the prediction principle of dynamic video processing technology.

(2) DC mode

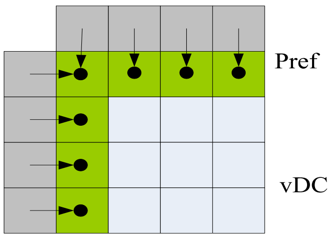

Figure 4 Schematic diagram of reference pixel average value

Figure 4 is a schematic diagram of the average value of reference pixels. In the DC mode, the predicted pixel value is usually the average value of the uppermost row and the leftmost column. The specific algorithm is as follows:

The average value v of the pixels on the left and above the DC mode, as shown in formula 2:

$$V = (\sum_{a=0}^{S-1} p[a][-1] + \sum_{a=0}^{S-1} p[-1][y] + S) >> (k+1), k = \log_2(S) \tag{2}$$

The pixel value in the upper left corner (R 0,0) is as shown in formula 3:

$$pred[0][0] = (p[-1][0] + 2 \times dcVal + p[0][-1] + 2) >> 2 \tag{3}$$

The pixel value of the first row (R 0,1 ~R N,02) is shown in formula 4:

$$pred[a][0] = (p[a][-1] + 3 \times dcVal + 2) >> 2, a \in [1, S-1] \tag{4}$$

The pixel value of the first column (R 1,0 ~R N2,0) is as in formula 5:

$$pred[0][b] = (p[-1][b] + 3 \times dcVal + 2) >> 2, b \in [1, S-1] \tag{5}$$

For any pixel value, as formula 6:

$$pred[a][b] = dcVal, a, b \in [0, S-1] \tag{6}$$

(3) Angle mode

Except for the offset value corresponding to the horizontal and vertical mode is 0, the other modes are equivalent to the offset in the horizontal or vertical mode. In addition to the offset value corresponding to each mode, some prediction modes also have corresponding contra-angle parameters. The corresponding table of mode and offset value and contra-angle parameter is shown in Table 1:

Table 1 Correspondence table of mode and offset value and contra-angle parameter

model	Offset value	Diagonal parameters
10	0	
11	-2	-4096
12	-5	-1638
13	-9	-910
14	-13	-630
15	-17	-482
16	-21	-390
17	-26	-315
18	-32	-256

When the angle prediction mode is greater than or equal to 18,

$$ref[a] = p[a-1][-1], a \in [0, S] \tag{7}$$

$$ref[a] = p[-1][-1+(a \times D) >> 8], a \in [-1, S \times O] >> 5 \tag{8}$$

In formula 7 and formula 8, ref[x] represents the reference sample array, and invAngle(D) represents the contra-angle parameter, intraPredAngle (O) represents the offset value, and calculates the position in the Ref of the current pixel corresponding to the reference pixel, iIdx (I) represents the index variable, expressed as formula 9.

$$I = ((b+1) \times O) >> 5 \tag{9}$$

Calculating the weighting factor iFact(F) of the reference pixel corresponding to the current pixel, the formula is formula 10:

$$F = ((b+1) \times O)\,\&\,31 \tag{10}$$

If F is not equal to 0, the pixel value calculation method is as shown in formula 11:

$$pre[a][b] = ((32-F) \times ref[a+I+1] + F \times ref[a+I+2] + 16) >> 5 \tag{11}$$

If F = 0, the pixel value calculation method is as shown in formula 12:

$$pre[a][b] = ref[a+I+1] \tag{12}$$

If the vertical mode is 26, the pixel value calculation method is as formula 13:

$$pre[a][b] = Clipl_Y(p[x][-1] + (p[-1][b] - p[-1][-1]) >> 1)) \tag{13}$$

When the angle prediction mode is <18, the method of calculating pixels is as follows:

When O is less than 0, as in formula 14:

$$ref[a] = p[-1+((a \times D+128) >> 8)][-1], a \in [-1, S \times O] >> 5 \tag{14}$$

When O is greater than or equal to 0, as in formula 15:

$$ref[a] = p[-1][a-1], a \in S+[1, S \times 2] \tag{15}$$

In all cases, as in formula 16:

$$pred[a][b] = ref[b+I+1] \tag{16}$$

3.2 Platform Demand Analysis

Food safety information traceable systems play an increasingly important role in social food safety supervision and problem food recalls [16]. In the practice of food safety supervision in China, the traceability system has been introduced into pilot projects in some regions and specific food safety projects [17-18]. When introducing a food quality information traceability system, starting from the cost and efficiency of the introduction, the industry that is suitable for the introduction and the specific product type to be introduced must first be considered. Different industries and product types will have different effects on the implementation effect and economic benefits of the traceability system [19]. All in this article, we will focus on the sources of ingredients of the merchants, and use this as the source for unified deployment.

3.3 Platform Function Framework

In view of the platform's demand analysis, we design and analyze the functions. Figure 5 is the overall design of the platform.

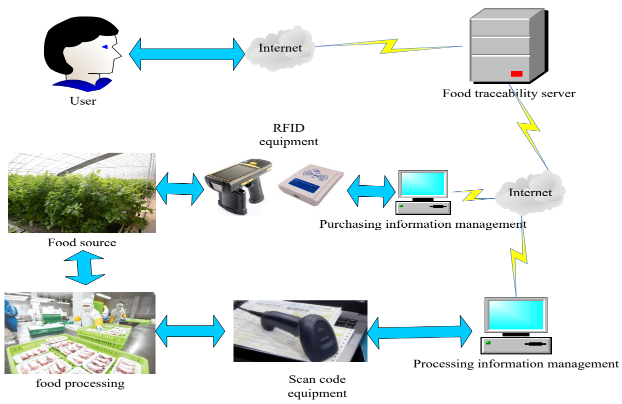

Figure 5 Schematic diagram of traceable system information hardware

In Figure 5, the food traceability system is oriented to users, which is the consumer; oriented to food sources, is the procurement system; oriented to food processing, is the processing system. These systems and users are linked by a food traceability system, and the databases between the systems are shared, thus keeping the system unblocked. In the procurement system, the online shopping platform needs to summarize the ingredients needed by the merchants, and then purchase them uniformly, so as to avoid the possibility of messy ingredients. Through the procurement system, RFID technology is used to identify the food, so that the source of the food can be found, and the principle of one item, one code is guaranteed. After the purchase of food materials is the processing link, the processing of food materials is also in accordance with the principle of uniformity, unified entry on the processing system, and the processed food is coded. Then the code scanning equipment is used to identify and enter the warehouse, and the food that is identified incorrectly or unidentified is prohibited from flowing to customers. Finally, the procurement and processing system delivers the food to the online meal shopping platform, and uses the traceable source code to identify it after use. The customer uses the APP of the traceability system to identify the traceable source code on the network opponent. If there is a problem, there is a special complaint channel.

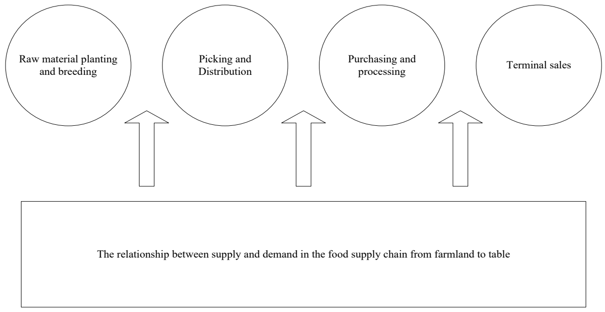

Figure 6 Relationship between supply and demand in the food supply chain from farmland to table

As shown in Figure 6, this is a supplementary process to the two systems of food procurement and food processing. The system shows two lines. The process of food from raw materials to finished products is not explained in detail. As can be seen from Figure 6, the food is a series of operations from raw materials to subsequent structure production, and they are closely arranged, and no other steps that affect the quality of the food will be inserted in the middle. Therefore, it can be marked with a uniform bar code. Every time a process is added, the corresponding identification code is added to the bar code, so the length of the identification code will also change.

Name:XXX Merchant

(02) 65489165489544 (646) 102525014

Figure 7 Schematic diagram of barcode setting

As shown in Figure 7, the identification code for the processing stage of the dish is a barcode, the upper left corner of the barcode is the name of the food, the upper right corner is the name of the processing factory, and the bottom is the barcode number of the processed dish. Because such a number is particularly simple, it is more convenient to generate, and it is also very convenient to recognize.

3.4 System Database Design

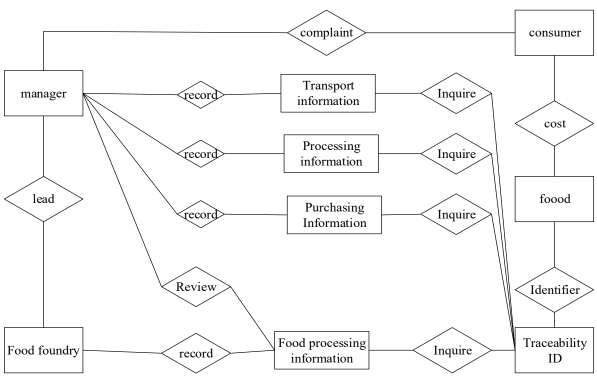

Figure 8 System database entity attribute diagram

The general idea of system database design: the convenience of information query and the effectiveness of product traceability information are the basic goals of the design [20]. The system uses managers to regulate and control the whole, and has relatively high authority in the system. The manager is responsible for the generated trace source code [21-22]. As shown in Figure 8, the entire database is linked to the source code by the administrator. All information contained in the traceability source code is also audited and recorded by the manager. Especially for the reasonable deployment of the two systems of food procurement and processing, it is the guarantee of the correct traceability of the source code.

(1) The design of the system's mobile APP

Because the food shopping platform is a complex application in the Internet of Things, and most of the use of the food shopping platform is carried out through smart device apps. So it is necessary to design the mobile APP.

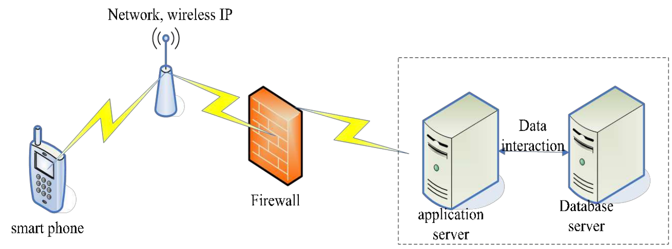

Figure 9 Mobile APP demo structure diagram

As shown in Figure 9, the smart phone links the online food shopping platform through the Internet and wireless ip, and the database of the online food shopping platform and the database of the food traceability platform are connected to each other. For the security of the database, there is a firewall to intercept it. Due to the exchange of information, customers can order food on the platform while scanning the merchant's food traceability source code for food traceability inquiries.

4. Results

4.1 Recognition Accuracy

We selected samples from three merchants with high traffic on the online food shopping platform. Each merchant selected 100 dynamic QR code data, which was identified by the system, and the accuracy and time of their identification were recorded. In the experiment, the recognition is correctly expressed as 1, and the incorrect is expressed as 0, and then the efficiency of its recognition is judged.

Table 2 Recognition accuracy rate

Merchant	Accuracy
A	93%
B	92%
C	93%

The most important thing in the entire system is the accuracy of the recognition, because only the content of the traceable source code can be accurately identified to meet the system design requirements. As shown in Figure 10, the food traceability source code identification results of the three ABC merchants on the online food shopping platform are respectively. It can be clearly seen that the identification time of the traceability source code of any merchant conforms to a relatively normal time series, and the time runs between 1-5 seconds. There is no situation where it gets stuck without recognition, and the overall recognition process is relatively stable.

Regarding the recognition accuracy of Table 2, the accuracy of different merchants is also above 90%. This is because the recognition process of the QR code is in motion, which has a certain impact on the effect of intra prediction. In addition, the array of pixels in the two-dimensional code is relatively dense, which will increase the difficulty of the system's prediction, which is still considerable overall.

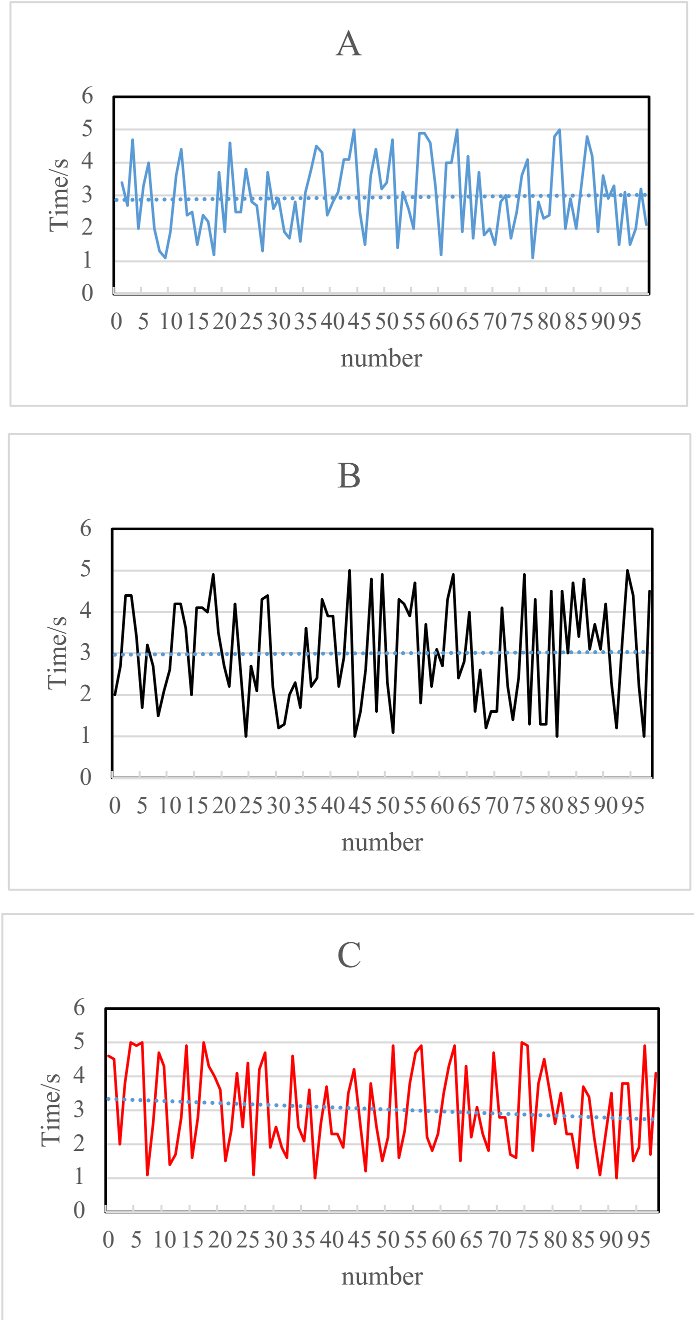

Figure 10 Running time chart

4.2 System Performance Test

For system performance testing, the JMETER tool sets up an automatic running tool that can simulate the actual client's operating conditions. For example, when using the query function, in reality, a large amount of data and the number of logged-in users will be generated in a short time. The test should simulate the most severe situation, and the response time of the system should be less than 5 seconds when the number of people and the number of queries reaches the maximum. The test results are shown in Table 3.

Table 3 System query the number of simulated users and program execution

Test items	NO.1	NO.2	NO.3

Number of simulated users_duration	350_3M	1050_10M	2100_10M
Number of pending transactions	4096	19957	39896
Number of execution passes	4096	19956	39884
Average number of successful transactions per second	22.75	33.96	65.15
Minimum system response time	1.021s	1.032s	1.080s
Average system response time	1.103s	2.625s	3.145s
Maximum system response time	3.145s	5.455s	9.990s
Program success rate	100%	100.00%	99.32%
Average hits per second	169.535	163.221	161.332
Average throughput	1956639	1959096	2043519

Through the analysis of the data obtained from the first test, the food query module can run normally during the first test, and the response time and speed of response can meet the requirements. And when the number of simulation usage in the same time of the second test doubles to 1050, the success rate of data interaction is 99.999%, and the average response time of the system is within the required range. In the third test, when the number of users reached 2100, the system's interaction success rate dropped to 99.315%, but the average response time was still within the system requirements. After the performance test, the test results of the system meet the requirements.

5. Discussion

There are an increasing number of commercial Internet apps nowadays, but less food traceability system for online food food shopping. The internet shopping platform is comprised of a number of distinct components. The distance between diverse merchants and the platform's insufficient management might easily result in poor food quality. The purpose of this article is to discuss the design of a food traceability system. First of all, this article gives a brief introduction to the current status of online shopping platforms and the Internet of Things. Then the paper discusses the Internet of Things technique in full, including the details of RFID technology. Afterwards, we design the food traceability system for online meal shopping platform as well as analyze the effectiveness of the system . The numerical result is satisfactory, and the system recognition rate can reach more than 90%.

Availability of data and material: Data is confidential and not public.

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Authors' contributions: X.Z has completed all the work related to this paper.

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List of Abbreviations

Abbreviations	Explanation
IoT	Internet of Things
RFID	Radio Frequency Identification
IoMA	Internet of Management
BCT	Bandwidth Coding Technique
APP	Application
GPS	Global Positioning System

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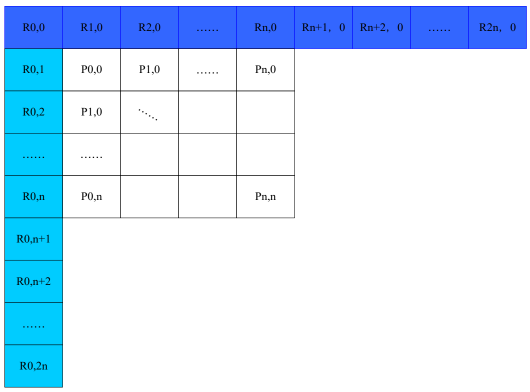

Figure 1 Adjacent reference pixel position template

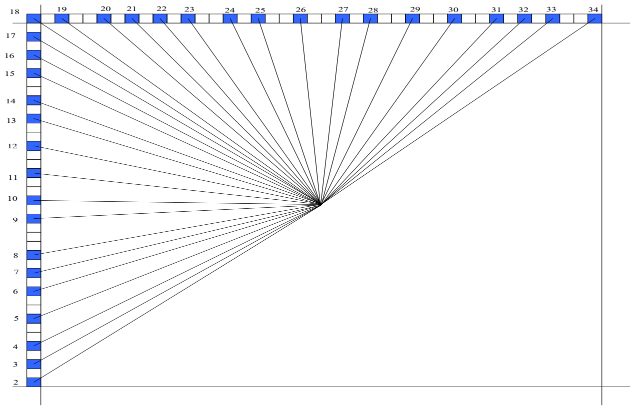

Figure 2 33 kinds of angle prediction direction

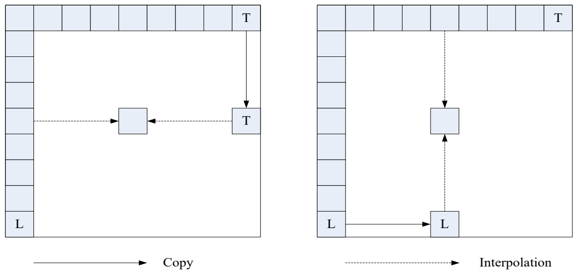

Figure 3 Schematic diagram of pixel predicted values in Planar mode

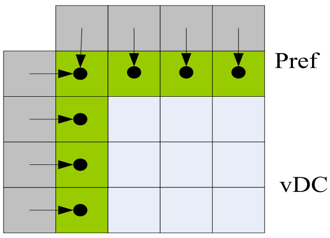

Figure 4 Schematic diagram of reference pixel average value

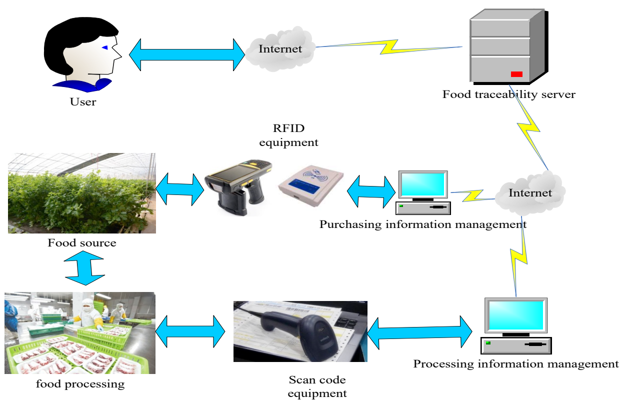

Figure 5 Schematic diagram of traceable system information hardware

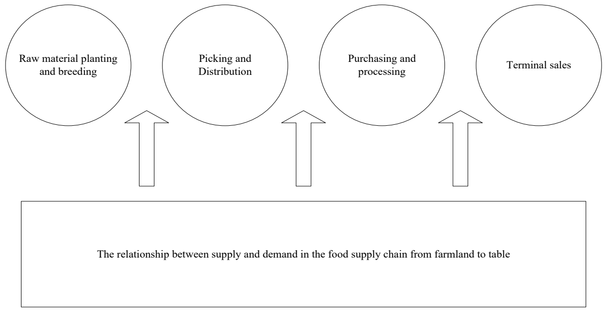

Figure 6 Relationship between supply and demand in the food supply chain from farmland to table

Name:XXX Merchant

(02) 65489165489544 (646) 102525014

Figure 7 Schematic diagram of barcode setting

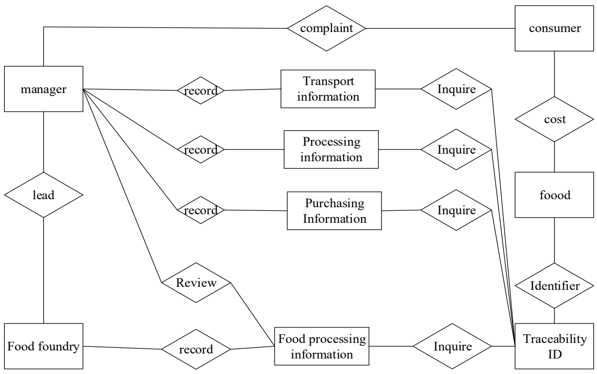

Figure 8 System database entity attribute diagram

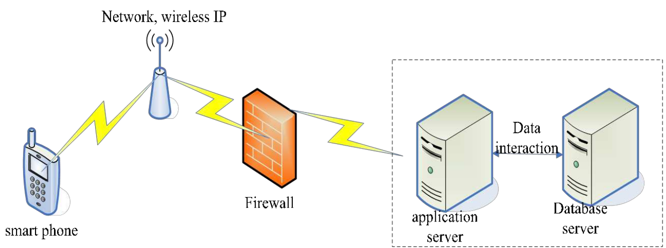

Figure 9 Mobile APP demo structure diagram

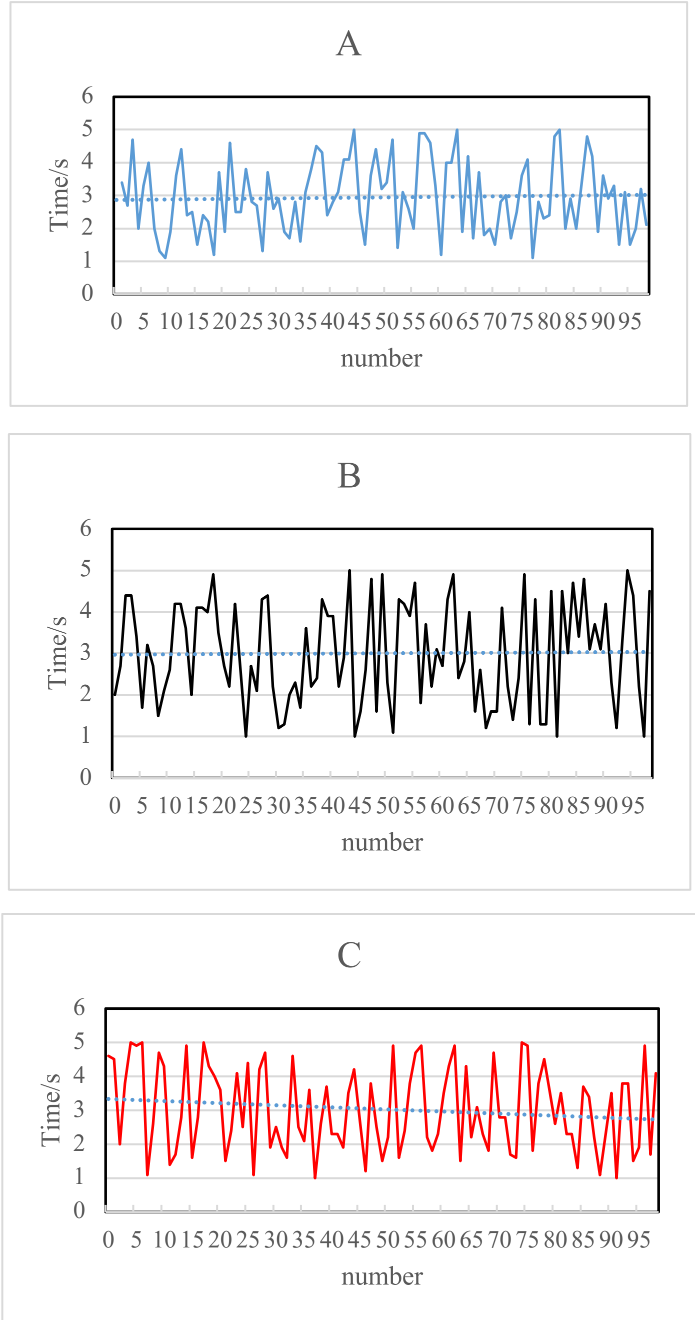

Figure 10 Running time chart