Construction of Simplified Traceability System of Agricultural Products Based on Android

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Abstract. The complex agricultural supply chains make it difficult to validate whether agricultural products meet the quality standards. In the supply chain of agricultural products, traceability system is an effective means to ensure the quality and safety of agricultural products. In this study, an easy-to-use simplified traceability system of agricultural products (STSAP) for small and medium-sized enterprises was constructed based on Android. The proposed STSAP provided a high level of traceability and had the characteristics of friendly interfaces, simple operation, and automatic generation of traceability files. STSAP consisted of six functional modules: account management, site management, planting materials management, agricultural activity management, processing management, and traceability files management. These modules recorded soil fertility, crop growth stages, fertilization, irrigation, and pesticide application. Thus, this study helps farmers improve agricultural production and helps consumers trace production processes and transaction records.

1. Introduction

Excessive use of chemical fertilizers and pesticides increases the content of chemical residues in soil. These residues further destroy the soil structure and ecological environment[1]. As a result, agricultural products grown in these soils usually contain harmful substances such as pesticide residues and heavy metals. The growing concern about food safety and environmental pollution has boosted interest in traceability across the supply chain. Therefore, it is necessary to develop a traceability system that can track the detailed information of farming methods and agricultural products safety[2].

In recent years, research interests have focused on integrating traceability systems with radio frequency identification (RFID), Internet of Things, and mobile Internet[3,4]. For example, the traceability system based on RFID and Near Field Communication (NFC) was suitable for livestock products with high economic value, such as sheep meat [5] and pork[6]. Likewise, the traceability system based on the Internet of Things was suitable for closed and controllable application scenarios, such as chicken farms [7], vegetable greenhouse [8], and vegetable cold chain[9]. By contrast, the traceability system based on RFID, Internet of Things, video, and WEBGIS was suitable for regional application scenarios, while the traceability system based on blockchain technology[10] was suitable for the application scenarios that require accurate information.

However, the long traceability chain and high use-cost caused the inefficiency in practical application[11]. Wu et al.[12] proposed a traceability system of food supply chain based on Android using pictures and videos of farm procedures. Yang et al.[13] presented a traceability system based on Android using RFID and QR codes. Mao et al.[14] discussed how to apply Android mobile phones to the traceability of food products. Overall, the systems based on mobile phones were more efficient than those based on WEB in collecting traceability information. Nonetheless, the existing systems based on mobile phones were not able to collect the complete traceability information. Therefore, the objective of this study was to build an Android-based traceability system for tracing the agricultural products grown in small and medium-sized enterprises. After this system was developed, it was used to help farmers standardize production procedures and enhance the safety level of agricultural products.

2. Traceability chain design

This study investigated many enterprises, which produced melon, apple, tea, and yam, and was familiar with the production flow. We collected the process information, such as agricultural operations, personnel management, and planting materials procurement, and meanwhile collected the technical standards for tea (NY/T 1763-2009), grain (NY/T 1765-2009), vegetables (NY/T 1993-2011), and fruits (NY/T 1762-2009). Finally, the UCC/EAN-128 coding method was adopted as traceability code.
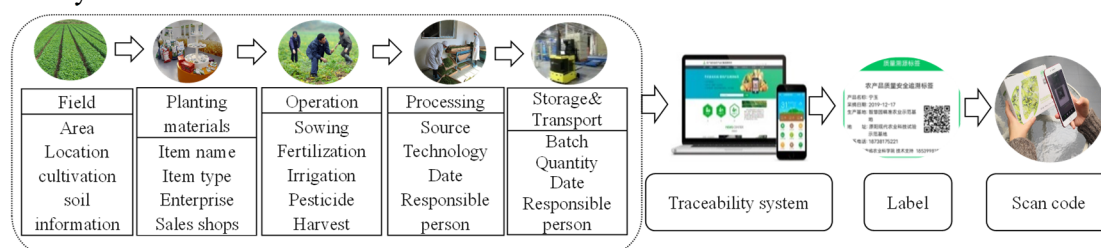

Figure 1. Agricultural products flow

A traceability system was to collect, exchange and manage the critical information in the supply chain. Customers can precisely identify the origin and authenticity of various information in the supply chain. Figure 1 illustrates the existing product flows in the supply chain of small and medium-sized enterprises. This study identified the supply chain participants and their corresponding functions and found five participating entities and their role as shown in Figure 1, including farmer, planting materials company (selling fertilizers, pesticides, and seeds), agricultural products processor, retailer, and customer. The farmer bought seeds, fertilizers, and pesticides from the materials company and then recorded the crop growth details at intervals after planting. The processor purchased the agricultural products and prepared the finished product. A retailer sells products directly to customers. According to these investigated enterprises, this study established the following standardized business process: first, record the number and fertility of plots and sort out the common-used planting materials. Arrange the previous and subsequent crops before planting, and then record the fertilization, irrigation, processes, and harvesting, and finally print the product labels.

3. System design

3.1. System architecture

In this study, a six-layer development framework was adopted in the simplified traceability system of agricultural products (STSAP), as shown in Figure 2. The figure shows that the bottom layer was the object-relational mapping framework, Hibernate, directly connected to the database. The second layer was the data access object layer that provided a database access interface. The third layer was the service layer that provided all kinds of business operations. The fourth layer consisted of the Mini

Program service connector Servlet. The fifth layer was the display layer used to show the application of traceability services. The sixth layer was the user layer that included regulatory departments, enterprise administrators, cooperative administrators, employees, and other users.
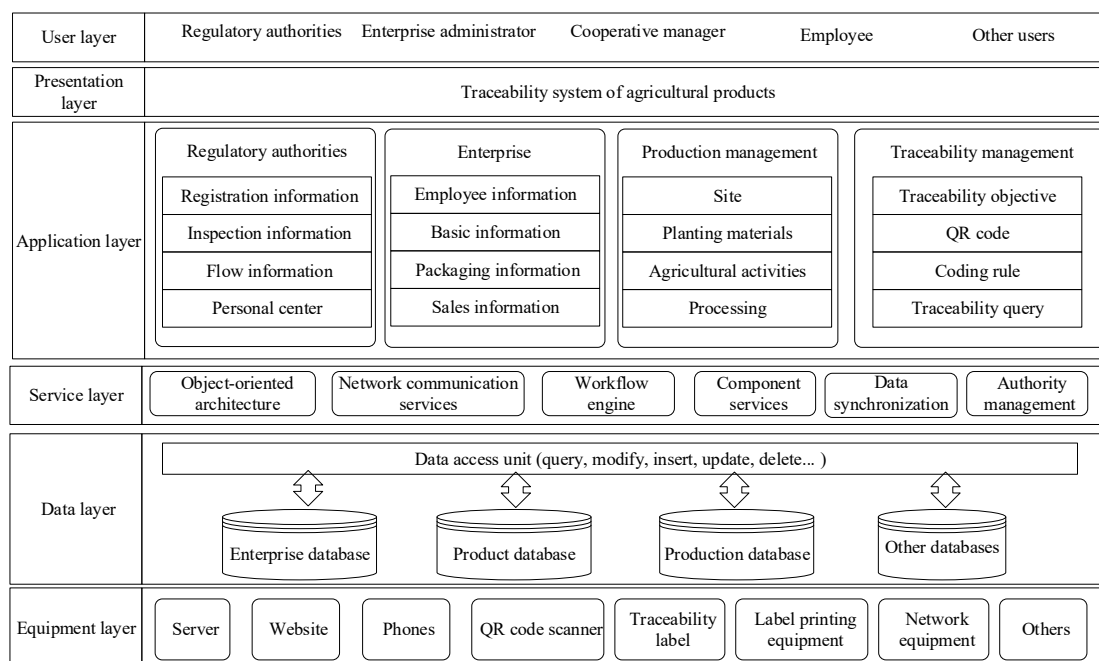

Figure 2. Android-based traceability system architecture

3.2. System function

STSAP was composed of six functional modules, as shown in Figure 3. (1) Account management was used to register, modify or delete enterprises or employees, and included two sub-modules of enterprise users management and employee users management. The registration information of enterprise users included name, address, phone numbers, business license, and certification certificate. The registration information of employee users included names and phone numbers. (2) Site management consisted of two sub-modules: field management and soil fertility management. The field management module was convenient for users to manage different fields. The soil fertility module recorded the fertility and heavy metal content of soil before planting. (3) Planting materials management recorded names, types, specifications, production enterprises of planting materials. (4) Agricultural activities management recorded the agricultural activities from sowing to harvesting and consisted of six sub-modules: growth season, fertilization, pesticides, irrigation, growth, and harvesting. (5) Processing management recorded the processing conditions that included raw material, packaging, processing technology, workshop, processing date, net content, and packaging material. (6) Traceability files management was composed of three sub-modules: automatic generation of traceable files, files preview, setting and printing labels.
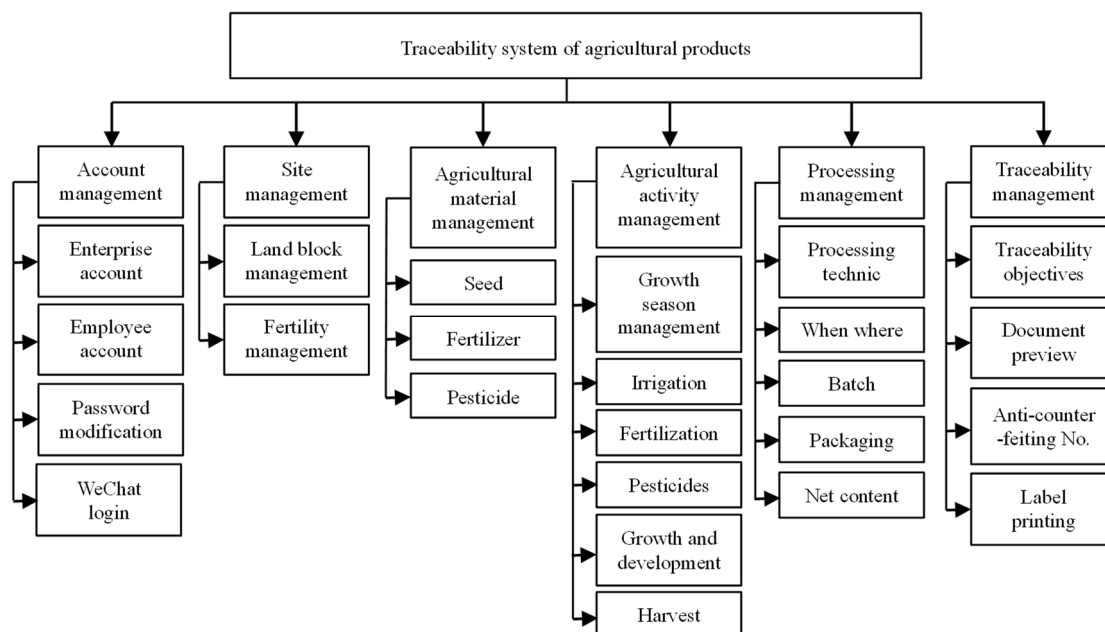
Figure 3. Structure diagram of traceability system

3.3. System development technology

The prototype of STSAP was based on system architecture, data flow diagrams, and database designs. STSAP was composed of front-end application and back-end application. The front-end application was built on an Android platform, while the back-end application was based on a Web platform. After being developed, the database was hosted on the cloud that allowed near real-time data acquisition processes to integrate and communicate with all actors. Therefore, the administrators and users easily queried the traceability information of agricultural products using WeChat. The Android application was designed and implemented in Android Studio and utilized SQLite as data management tools. The Web application utilized MySQL, and the user interface used PHP, HTML, CSS, and JavaScript.

The database tables consisted of eight tables depending on the design of STSAP, as shown in Table 1.

Table 1. Fields of the database tables

NO.	Table name	Table field
1	Users table	Enterprise name, province, city, users name, and phone numbers.
2	Plots table	Plot name, plot area, plot location, and cultivation mode.
3	Soil fertility table	Date, soil type, organic matter content, available N content, available phosphorus content, available potassium content, pH, and heavy metal content.
4	Fertilizer table	Item name, item type, enterprise, packaging, and specifications.
5	Growth Season table	Plot No., cultivars, sowing date, and expected harvest date.
6	Operation table	Fertilizer name, fertilization method and amount, pesticide amount, irrigation method and amount, and harvesting amount and date.
7	Processing table	Materials source, processing technology, processing workshop, and processing date.
8	Document table	Product information, soil composition, growth records, irrigation, fertilization, and applying pesticides.

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4. System development

4.1. Collecting soil and weather data
The primary data management module was composed of fertility management, land management, and planting materials management. Fertility management recorded soil fertility and heavy metal content. Furthermore, land management numbered the land plot. Planting materials management managed planting materials in the form of seed, seeding, fertilizers, and pesticides. STSAP recorded the soil fertility and heavy metal content of representative plots because enterprises generally selected several representative fields to determine soil fertility. Users numbered the plots with fixed planting patterns and entered the soil data into the plot management module.

4.2. Collecting daily production information
The production information management module comprised growth season management, agricultural activities management, and processing management. Growth season management provided technicians with a reasonably planting plan to arrange the previous and subsequent crops. Agricultural activities management was the most used function in STSAP and recorded agricultural activities from sowing to harvesting. This sub-module was efficient in collecting crop growth information by taking pictures of agricultural operation activities. These activities included fertilization, applying pesticides, irrigation, weeding, and harvesting. Processing management was applicable to the processed agricultural products that need to record the processing process, such as tea. The processing information included raw material origin, packaging, processing technology, processing workshop, processing date, net content, and packaging materials.

4.3. Generating and printing traceability label
The traceability management module (TMM) automatically generated traceability files by integrating the information of product, planting, processing, and certification certificate. TMM included files preview, label generation, and QR code printing. After harvesting, users previewed the detailed traceability files and then selected the label (providing two sizes: 80 mm*60 mm and 60 mm*40 mm) before printing. However, for high-end products such as tea, the anti-counterfeiting labels need to be printed in advance. Users should match the printer with BlueTooth with the mobile phone installed STSAP when they first used the STSAP.

5. Conclusions
By analyzing the characteristics of small and medium-sized enterprises, this study constructed the simplified traceability system for agricultural products based on intelligent terminals. STSAP was used to record the supply chain of agricultural production, including planting, harvesting, transportation, and sales. When customers used WeChat to scan the QR code, STSAP automatically called API to read the traceability files. Contrasted with other traceability systems, STSAP has the following characteristics: (a) Easy-to-operate, flexible and convenient. It is convenient to collect production information and print traceability labels in the field by using STSAP. (b) Low-cost. Collecting production information by clicking the keyboard and taking photos improves the efficiency of information input. (c) Strong expansibility. STSAP is compatible with Internet of Things and big data and allows third-party regulatory authorities to invoke traceability files.

Since 2015, STSAP has been developed and used in over 150 enterprises to help tackle the safety issues of agricultural products. STSAP have achieved good application effect in the characteristic agricultural products of Henan province, such as Lankao honeydew melon, Sanmenxia apple, and Xinyang tea. In the future research, STSAP provides the function of acquiring environmental data and video data of production sites and is compatible with the rapid detector of pesticide residues to detect agricultural residues online.

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