An Intelligent Shopping System based on UHF RFID

Zhankun Zhang¹*, Shenghan Liu¹, Xiaomei Yuan²

¹School of Software, Zhengzhou University, China, 450003
²College of Information Engineering, Zhengzhou University, China, 450003

*Corresponding author e-mail: zhangzk@zzu.edu.cn

Abstract. In the context of COVID-19, in order to solve the problems that customers need to spend more energy to find products in the supermarket, long checkout queue time, and cumbersome product management, optimize the shopping route of customers, accelerate the shopping process, and reduce the risk of infection; providers exceed Supplier's sales of goods, and then timely and purposeful selection of goods, simplifying the supply chain process between supermarkets and suppliers. This article designs a multi-terminal interactive intelligent shopping system based on UHF RFID to construct The shopping cart terminal, mobile phone APP terminal, data management system terminal, and three-terminal interactive system with RFID technology as the core are developed. The design uses the UHF RFID system to identify the information in the electronic tags of the goods, and through the navigation function, helps customers locate the desired goods, and realizes the functions of identification, information display, navigation and positioning, and settlement.

Keywords: RFID, Sensor Network, Internet of Things, Embedded System, Smart Shopping

1. Introduction

The construction of a modern economic system is inseparable from the optimization of the buying and selling process. This article is designed to contribute to this process. Customers often spend a lot of unnecessary time when they go to the supermarket to shop. For example, they cannot find the goods they need in the supermarket, queue up for weighing, and queue up for payment. Supermarket purchases and supplier supply information are not clear, the supply process is complicated, and the quantity of goods sold by supermarkets cannot be grasped in real time. In order to solve this problem, many customers choose to shop online to save time in searching for goods and queuing for payment. However, online shopping also has problems such as delayed delivery, fraudulent data, insecure delivery, and poor purchasing experience. In addition, the current epidemic situation in China has gradually stabilized, and
it has turned to the post-epidemic period of "internal defense rebound and external defense input". In order to reduce personnel contact, it is critical to optimize supermarket shopping methods and procedures. The main goal is to provide a technology oriented, low-cost, easily scalable, and rugged system for aiding shopping in person [1]. Although many smart shopping carts in China can meet the needs of some customers, their functions are still very limited, such as inaccurate calculation of fees, still queuing to pay, inaccurate positioning, and inability to provide good supermarkets and suppliers to directly control the sales of goods. Therefore, it is imperative to optimize customer shopping routes, speed up the shopping process, reduce the risk of infection, improve the customer's purchase experience, and optimize the procurement supply chain. And based on the quantity of goods purchased by customers, the information flow of the supply chain between the developer and the supplier is carried out to complete the multi-end intelligent shopping system from the supplier to the supermarket and then to the customer. Another benefit of this kind of system is that inventory management becomes much easier, as all items can be automatically read by an RFID reader instead of manually scanned by a laborer [2].

The overall architecture is shown in Figure 1.

1.1. Hardware design

The main components of the hardware system are Raspberry Pi, STM32F103ZET6, UHF-R200 UHF RFID radio frequency identification module, D-DWM-PG2.5 positioning module, SONY IMX307 image sensor module, HX711 pressure sensor module, Arduino, touch screen. Raspberry Pi is the host computer, which realizes data processing, is responsible for the communication function between hardware and software, and stores role information and product information. STM32 is responsible for the hardware control system of various components in this design. And because Raspberry Pi needs to be on a private network, it uses reverse proxy technology to redirect requests and responses to the public network [3]. Figure 2 shows the various devices of the hardware system.
1.2. Software design

The software is used by customers and businesses. When customers purchase goods, they can select their favorite product category on the touch screen of their mobile phone or shopping cart in advance. The system calculates the best navigation route based on the selection of the product and guides the customer to purchase the product. For bulk goods, customers can click on the self-service weighing function on the touch screen. After the product selection is completed, customers can pay with one click through the RFID checkout gate. Merchants can grasp the sales information of the goods in real time in the background, and intelligently generate sales orders and purchase orders according to the sales situation of the goods.

2. System implementation

This article divides the system into four modules, as shown in Figure 3. It includes positioning module, weighing module, UHF RFID product recognition module, image recognition module and visualization module. The modules work together to achieve the design goals.
2.1. Positioning module

UWB (Ultra WideBand) is an emerging technology in the field of indoor positioning. Compared with other positioning technologies, it has better performance and higher accuracy, and is more suitable for indoor positioning. STM32F103ZET6 is the main control chip, and STM32F103C8T6 is the calculation chip of the UWB positioning module. This article design uses three base stations, one location tag, and calculates the location information of the tag according to the TDOA location algorithm [4]. The main base station sends the data to STM32F103ZET6 through serial communication, and then displays the position information on the touch screen. Figure 4 shows the positioning principle.

\[ C \times (t_1 - t_3) = \sqrt{(x-x_1)^2 + (y-y_1)^2} - \sqrt{(x-x_3)^2 + (y-y_3)^2} \]  \hspace{1cm} (1)

\[ C \times (t_2 - t_3) = \sqrt{(x-x_2)^2 + (y-y_2)^2} - \sqrt{(x-x_3)^2 + (y-y_3)^2} \]  \hspace{1cm} (2)

Note: C is the speed of light, \( t_1 \), \( t_2 \), \( t_3 \) are the required time from the measurement point to the three base stations respectively, \( (x_1, y_1) \), \( (x_2, y_2) \), \( (x_3, y_3) \) are the three base stations A, B, and C. The position coordinates of the A base station is the origin of the coordinates by default.

Figure 4. TDOA positioning principle

2.2. Weighing module

The system uses HX711 weighing module to connect with Arduino for calculation. Arduino and STM32 transmit weight information through serial communication, and the information is displayed on the touch screen after calculating the price through Raspberry Pi. The power supply of the weighing module HX711 is 2.6–5.5V, the internal integrated stabilized power supply, on-chip clock oscillator, the sensor has 24-bit A/D conversion [5]. It has the advantages of high integration, fast response, and strong anti-interference. The cost of the whole machine is reduced, and the performance and reliability of the whole machine are improved.
2.3. **UHF RFID product identification module**

The identification module adopts UHF-RKF918, which supports the reading and writing of passive tags in the 800MHz-960MHz frequency band, the working voltage is 3~5V, and the reading and writing speed is greater than 60 sheets per second. The reader adopts the R200 UHF module with a multi-tag anti-collision algorithm architecture, which can be used in scenarios where the reading and writing distance is within 30m, and the distance is adjustable to meet the requirements of system design [6]. Customers can use mobile applications or touch screens to select products and calculate the total price of the products. The client sends a card reading request to the card reader, and the card reader can read out the label information on all purchased goods at one time and feed it back to the Raspberry Pi for information calibration, and feedback to the client for payment and other operations after the error is correct. Figure 5 shows the data flow of this module.

![Figure 5. Schematic diagram of product label recognition function](image)

2.4. **Image recognition module**

The system adopts BlueloverT3200 high-definition driver-free camera module, the photosensitive film type is 1/5 inch CMOS, and it can support Linux operating system. The video information collected by the touch screen on the smart shopping cart is compressed by H.264 encoding and passed the reverse proxy technology of the RTP/RTCP protocol in the following way, so the product information entered in advance can be identified [3]. The module data flow is shown in Figure 6.
Figure 6. Schematic diagram of image recognition function

2.5. Visualization module

The visualization module provides users with an interactive interface, which can select products, push promotional information, display current location, current role, task list, product order, weighing buttons, etc.

3. System experiment

3.1. Hardware experiment

After a large number of experimental tests, the hardware part of the system has the characteristics of low delay and high sensitivity.

The positioning can achieve an accurate error of about 10cm. Some positioning test data are listed in Table 1. The accuracy of image recognition is above 95%. Figure 7 is an image recognition test picture. The hardware deployment is good, and the communication between the modules is good. Different users can achieve the expected results on the system.

| X axis (cm) | Y axis (cm) | A base station (cm) | B base station (cm) | C base station (cm) |
|-------------|-------------|---------------------|---------------------|---------------------|
| 105         | 29          | 109                 | 171                 | 48                  |
| 99          | 33          | 104                 | 169                 | 50                  |
| 85          | 42          | 81                  | 158                 | 51                  |
Note: (X, Y) are the position coordinates; base station A is the main base station, which is the origin of the two-dimensional coordinate axis; base stations B and C are secondary base stations.

|   |   |   |   |   |
|---|---|---|---|---|
| 89 | 45 | 69 | 156 | 51 |
| 90 | 40 | 86 | 155 | 51 |
| 82 | 28 | 110| 156 | 49 |

Figure 7. Image recognition paper towel

3.2. Software experiment

The user can normally choose the product to purchase. The goods purchased by the customer can be navigated normally and displayed on the touch screen normally after the RFID recognition and payment. The touch screen display is shown in Figure 8.

Figure 8. Payment successful display

4. Conclusion

Experimental test based on the conclusion drawn from theoretical analysis. The system can effectively select the goods to be purchased through the mobile phone or touch screen. The system will display the fastest shopping route on the touch screen; when customers check out, they do not need to scan the purchased goods one by one, but one-click payment. Improve the experience of shopping technology. Moreover, the products on the market do not have RFID recognition payment or no positioning function,
so the system has great market potential and research value. However, the accuracy and stability of the system still need to be improved and improved.

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