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A Novel Smart Shopping System With New Payment Solution at Mini-Mart

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ABSTRACT

This paper presents a novel smart shopping system. This is a solution for an automatic purchasing equipment for mini-marts with integration of a QR code payment method. A system consists of a vending box (a touch screen, a computer), a store, customer baskets, wifi connection and a methodology of QR code payment. The customer orders a set of good items by interacting with a vending box via the touch screen, using non-cash payment method, and then waiting for the bank confirmation of receiving of money via the internet, finally, the system carries the selected items to the customer ‘s shopping basket by automatic transporting systems. The QR code payment method increases the convenience, the transaction speed, the ease of use, and time-saving; even reduces the risk of carrying cash and storing cash in the machine (for the owner). Many experiments were conducted to show the effectiveness and the performance of the proposed system.

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1. Introduction

Currently, vending machines are becoming more and more popular all over the world because of convenient use. Thanks to these vending machines, customers can buy items such as bread, cheese, soft drinks, gifts, fruit, umbrellas, etc. The vending machines are often found at bus stations, subway stations, stadiums, residential areas, and parks. To make a transaction with a vending machine, a customer needs coins, or even in the case of the improved machines, notes can be used but with a limitation of currency denomination. Even some vending machines were improved with a money receiving module when paying by using ATM and VISA cards; however, this payment transaction is still inconvenient.

A number of vending machine researches have been carried out [1]-[9], the author [1] proposed a design of a chocolate vending machine using IoT technology. This design used Arduino UNO board, a coin receiving module, an RFID card reader, RFID cards, servo motors, an LCD screen, infrared sensors. Article [2] proposed a wireless sales system based on RFID technology. This device uses an Arduino UNO board as the main controller, along with RFID tags and a card reader. The work [3] showed a prototype of vending machine which used the micro controller 8051. The article insists that the most important goal is to recognize and read the value of coins. Research [4] focused on product releasing systems. The machine accepts a variety of coins and products; in addition, the machine also uses cashless payment methods such as online payment solutions by using GSM modules. Besides, research [5] applied QR codes in mobile banking use. However, these vending machines have not yet applied QR code payment technology, which is able to overcome the limitations of payment of the traditional vending machines.

Most recently, the popularity of mini-marts has met the customer’s buying needs, and the mini-marts have more items than the vending machines. However, buying good items at mini-marts still has some shortcomings and inconveniences because the space is usually small and there is narrow parking space. Actually, customers come to mini-marts to buy a few items only; therefore, the steps of parking, entering the mini-mart, selecting goods, and getting in line to pay money are really inconvenient. To overcome these kinds of difficulties, this research proposes a solution for vending systems at mini-marts with a non-cash payment method (Figure 2). The system consists of a vending interface (touch screen, computer), a store, customer baskets, a wifi connection, and a methodology of QR code payment. A

customer orders a set of items by selecting them on the screen. After all items are listed in the virtual cart, the next step is payment. The system shows an according QR code of the bill, and the customer pays for purchased goods at the vending box by scanning a QR code with a smartphone. After the system confirms the receipt of money from the customer, the system controls the auxiliary conveyors and the main conveyor, transporting the selected items from the shelves to the customer baskets. The customer can get the good items by taking them out of the shopping basket and putting them in the plastic bags. The online payment application with a QR code is provided by banks or other payment service providers.

This solution of automatic purchase and integration of the QR code payment method at mini-marts can increase the convenience, the transaction speed, the ease of use, and the time savings, even reduce the risk of carrying cash and storing cash in the system. Furthermore, the non-cash payment eliminates the need to store small value notes or coins (for returning) or take out the cash of the full money box. As a result, the secure payment method overcomes the limitations of traditional payment methods using coins, notes, RFID cards, GSM, etc.

2. Operational principle of the proposed system

This study proposes an automatic vending solution at a mini-mart with a QR code payment method. The steps of doing an automatic transaction are depicted in Figure 1. Firstly, the customer selects and puts items in a virtual shopping cart via the touch screen; if the item selection is completed, the system moves to the second step, and the customer performs the payment by smartphone to scan the QR code that is showed on the screen (in this study using the MOMO e-wallet service). When money is received by the system‘s bank account, the system controls the auxiliary conveyors to push selected items to the main conveyor, which transports the selected items to the shopping basket.

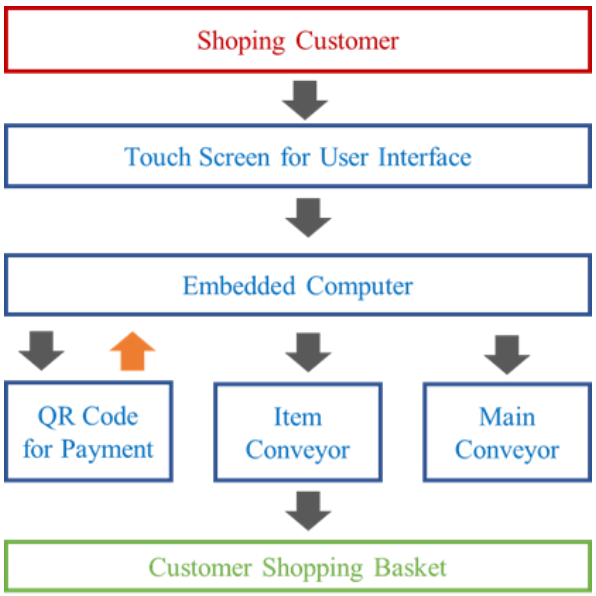

Figure 1. *Steps of ordering and receiving items.*

2.1. Elements and the operational principle of the vending system

The mini-market vending system consists of the basic blocks (numbered 1-9) as described in Figure 2, the function of each block is as follows: The cell (1) contains a type of item. The bottom of the cell is equipped with the auxiliary conveyor (2), which pushes the selected items to the main conveyor (3). The main conveyor (3), which is driven by the gear motor (4), receives items from the auxiliary conveyor and then transports the items to the shopping basket (5), which is placed in the bottom of the control box (6). The shopping basket (5) is used to store the products (items) that are selected by the customers. The control box (6) which contains the embedded computer (7), the power supply (8), and the touch screen (9), is utilized as the user interface for choosing items and controlling the operation of the whole system. The touch screen is also used for configuring the system parameters. In addition, the mini-market vending system also has air conditioning systems to keep goods at the appropriate temperature condition.

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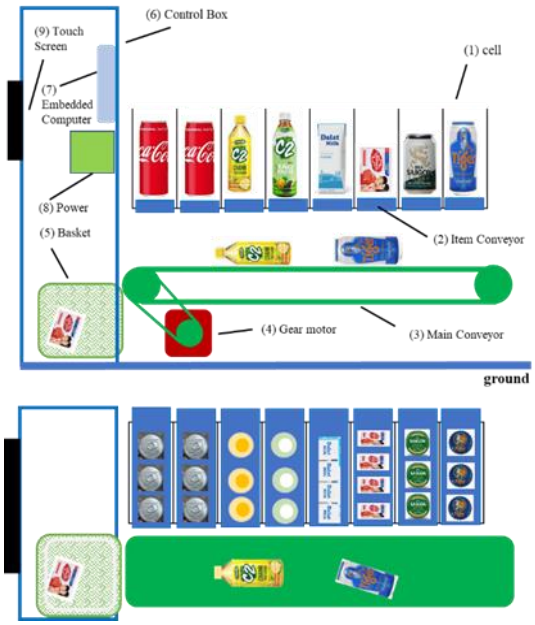

Figure 2. *Block diagram of system.*

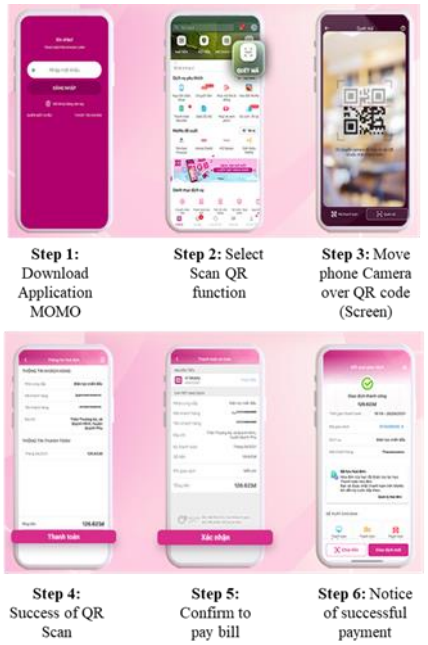

Figure 3. *Steps of QR payment.*

2.2. Cashless payment method

Previous-generation vending machines used cash transaction methodology, which required a customer to put notes or coins into the slot of the money receiving module, where a sensor recognizes the face value of the notes or coins. The machines then automatically push the selected items off the shelves and into the delivery trays. The system is equipped with a sensor to detect whether the product is falling out or not. In the case of no product falling out, the machine automatically refunds the customer. This payment method still has inconveniences such as currency denomination limitation, getting stuck with cash, issues of unrecognized cash. Therefore, to overcome this limitation, this study integrated QR codes in a mini-mart vending machine. The customers only need the smartphones of which bank applications or e-wallets are installed to make transactions. There are many payment providers using QR codes, such as: VNPay, Vietin, ZaloPay, MoMo, etc. In this prototype system, the QR Code, which is provided by MOMO company, is utilized. The customers take the steps to pay for the ordered items as follows (Figure 3):

Step 0: Download and register MOMO e-wallet. If customers already install the MOMO e-wallet, this step is skipped.

Step 1: Open the MOMO wallet, select the "scan code" feature.

Step 2: Move the scanning frame to the area of the QR code which is shown on the touch screen.

Step 3: After successful scanning, invoice information will be displayed. Check the information and click “Payment”.

Step 4: Select “Confirm” to complete the bill payment.

Step 5: The screen will display the transaction status: “payment confirmation is successful”. Then the vending system delivers the selected items to the customer by using the automatic conveyor transportation systems.

3. Vending system structure and control system

In this study, based on the design of the operational principle and the structure of the vending system, an actual system was built as the demo prototype version, which has 5 auxiliary conveyors (each conveyor contains only a type of item) and one main conveyor (used to carry the items to customer baskets). The block diagram (Figure 4) shows the components and corresponding functions in the

vending system. The touchscreen is used for selecting items and displaying a QR code. The customer pays the bill by opening the application and scanning the QR code. Once the system account receives the money from the according customer, the computer controls the power circuit to rotate the auxiliary conveyors to push selected items to fall into the main conveyor. Finally, the main conveyor transports the items to the shopping basket.

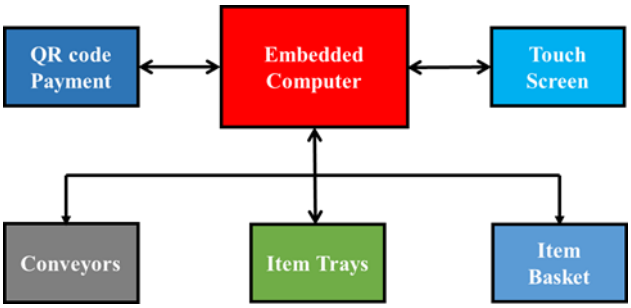

Figure 4. *Block diagram of system structure*

To buy products at the mini-mart vending system, the customer interacts with the touch screen (Figure 6), of which the specifications are: a size of 7.0 inches, 1024×600 resolution, capacitive touch, and outer dimensions of 165×124 mm. A full HD touch screen (size 7 inches), which is connected to the Raspberry Pi controller (Figure 5), is shown in Figure 6.

The demo system contains 5 types of items. The number of items per storing tray is 3. The average duration from choosing to receiving an item is t_1 [s]. A customer buys 3 of the same products, only taking $t_2 = 3 \times t_1$ [s]. The QR code Momo payment processing duration is $t_3 = 60$ [s]. Then, the total transaction duration is $T = t_2 + t_3$ [s].

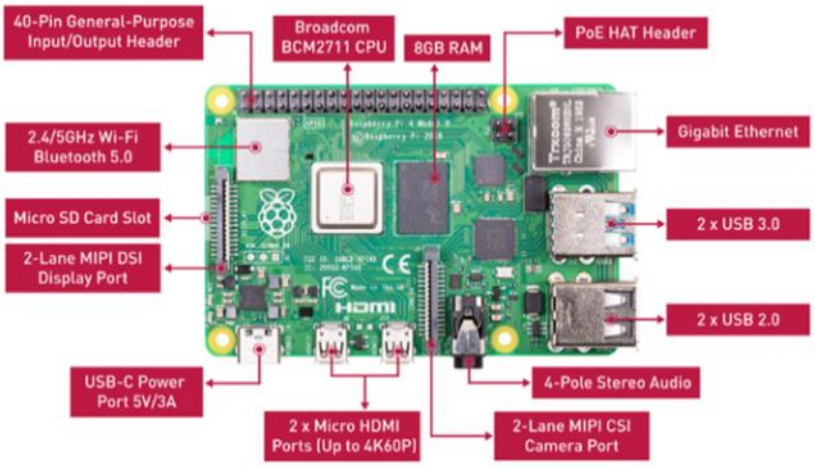

Figure 5. *Rassperry Pi 4 - Embedded Computer*

The mini-mart vending system uses Raspberry Pi 4 computer (Figure 5) as the controller. The computer connects the touchscreen via a cable as shown in Figure 6. The basic specifications of the Raspberry Pi 4 are as follows: Broadcom BCM2711, Quad-core Cortex-A72 (ARM v8) 64-bit SoC @ 1.5GHz; RAM: 8GB LPDDR4-3200 SDRAM; Wifi: 2.4 GHz and 5.0 GHz IEEE 802.11ac wireless.

4. Programing of the system operation

The diagram (in Figure 7) shows the flow chart of system operation. The items are selected on the screen by the customer, and then the ordered items are shown in the virtual basket. The customer performs the payment step when the system shows an appropriate QR code of the invoice; the customer uses MOMO application to scan the QR code (shown in Figure 8). Once the system account receives the money from the customer, the auxiliary conveyors and the main conveyor transport the selected items from the shelves to the shopping basket. The customer can take them and put them in the plastic bags. The QR code payment application is provided by the banks or the other payment service providers.

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The system of conveyors transports items from the cells to the shopping basket. The auxiliary conveyor runs 7 cm in length with a duration of 2.5 [s] to push an item out. Then it takes 3 [s] for the item to fall down the main conveyor. The main conveyor receives and transports the items to the shopping basket. The main conveyor rotates continuously to ensure the less time of delivering to customers.

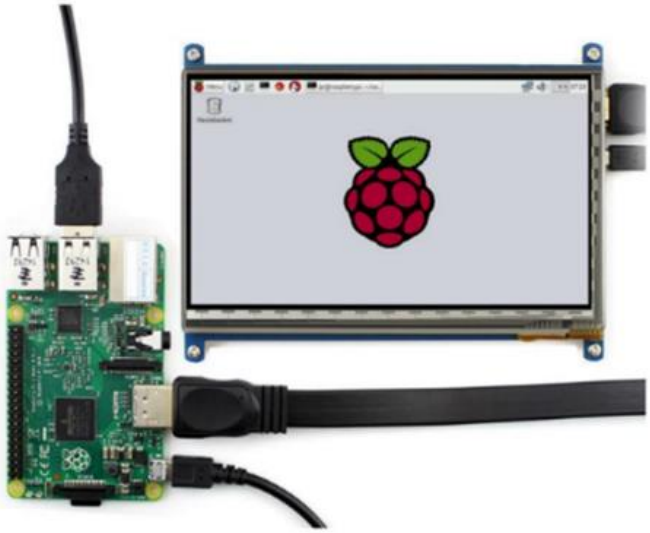

Figure 6. *Wiring connection between touch screen and Raspberry Pi4.*

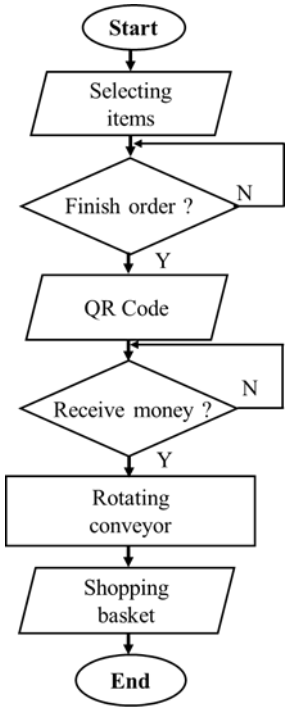

Figure 7. *Flow chart of system operation.*

Figure 8. *QR Code issued by MOMO.*

To perform payment using a QR code that is issued by the MOMO e-wallet, it is necessary to connect to the MOMO server by programming to initialize and retrieve data via the MOMO API as follows: Initialize the data connected to the MOMO server API. Generate a payment QR code and retrieve the QR code as an image. Check transaction. Get transaction history from the web API and analyze the data for comparison to confirm the corresponding order payment.

The system controller, which uses the Raspberry Pi, is programmed to transport the ordered items from the shelves to the shopping baskets. The GPIO programming library, which is a package of libraries, is used to control the GPIO pins of the Raspberry Pi. This package provides a class that contains controller functions. The flowchart control of the algorithm is shown in Figure 9.

5. Experimental and Results

5.1. System Prototype

A prototype vending system that is manufactured, assembled, and programmed is shown in Figure 10 and Figure 11. For the convenience of operating the demo, the auxiliary conveyors, the main conveyors, the embedded computers, and the display screen are placed in the same box with the external dimensions of 40×50×120 [cm] in length × width × height [cm].

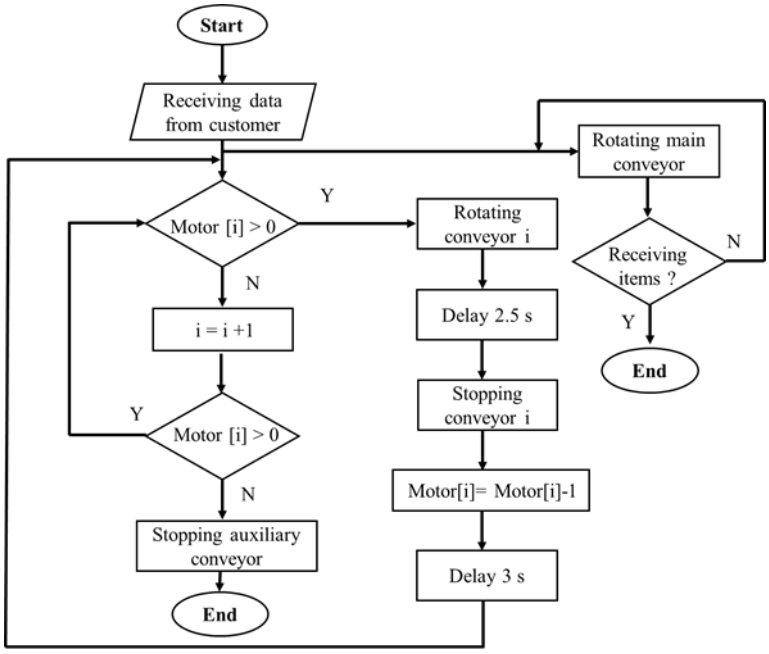

Figure 9. *Flowchart of the control delivering process.*

Figure 10. *Auxiliary loading conveyors.*

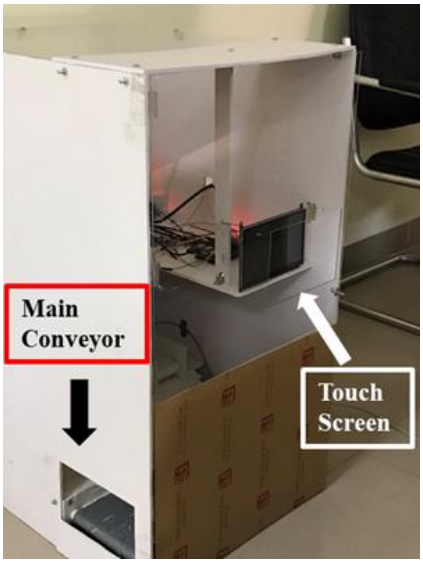

Figure 11. *Completed mini mart vending system.*

This experiment is carried out for 5 types of items. The size of each item as follows:

• Beer (can): diameter d = 66 [mm], height h = 115 [mm].
• Soft drink (can): volume 250 [ml], diameter d = 66 [mm], height h = 92 [mm].
• Pure water (bottle): volume 500 [ml], diameter d = 61 [mm], height h = 220 [mm].
• Soft drink (plastic bottle): diameter d = 60 [mm], height h = 221 [mm].
• Soft drink (can): volume 250 [ml], diameter d = 66 [mm], height h = 92 [mm].

To apply this solution to a specific mini-mart, the configuration of the system could be appropriately arranged within a store so that the storage system can contain many types of items. The control box, which contains display screens and embedded computers, should be placed at an appropriate location where customers can access conveniently.

Figure 12. *The trial operation of the proposed system*

Table 1. *Number of trial transactions and results*

No.	Ordered items	Time [s]	Received items	Result {✓:pass}	No.	Ordered items	Time [s]	Received items	Result {✓:pass}
1	3	76.39	3	✓	*16*	4	82.12	4	✓
2	5	87.87	5	✓	*17*	3	76.59	3	✓
3	6	93.62	6	✓	*18*	3	76.64	3	✓
4	4	82.58	4	✓	*19*	4	82.45	4	✓
5	3	76.28	3	✓	*20*	5	87.53	5	✓
6	5	86.56	5	✓	*21*	6	93.47	6	✓
7	6	92.78	6	✓	*22*	3	76.80	3	✓
8	2	71.06	2	✓	*23*	4	82.23	4	✓
9	3	75.94	3	✓	*24*	5	87.35	4	✓
10	5	87.41	5	✓	*25*	4	81.73	4	✓
11	4	82.06	4	✓	*26*	5	87.55	5	✓
12	3	76.52	3	✓	*27*	4	82.30	4	✓
13	5	87.43	5	✓	*28*	4	82.56	4	✓
14	3	76.68	3	✓	*29*	4	81.78	4	✓
15	2	71.53	2	✓	*30*	3	76.58	3	✓

5.2. Result of trial transactions and discussions

The proposed system performs 30 trial transactions (Figure 12). This experiment is operated in a condition of a limited number of 15 items. Before taking a trial, the items should be reloaded. Table 1 shows the number of ordered items and the received items for each trial. The experimental results show that the system continuously operates without faults (Table 1). The average time for buying one item is 65.566 [s].

The system is a miniature version that used as a testbed of the real system. In practice, the warehouse is larger, contains many items, and the quantity of each item is also bigger. In this case, the conveyor systems are also designed suitably so that the system is able to continuously transport the items to the shopping carts (baskets). The number of counters also increases to 3, 4, or more to meet the needs of the larger number of customers. However, this suggested solution for an automatic mini mart requires 2 counters, as in reality, the cashier of a mini mart needs about 2 counters. For medium and large supermarkets, the corresponding number of cashier counters is also increased corresponding to the number of customers. In the transaction process of buying items, similar to ATM machines, the system sometimes encounters problems such as extra items being delivered, lack of items, wrong items, delivered broken items, etc. The customer should take a picture of the bills and delivered items and then call customer service to get support.

This proposed system allows customers to select items on the screen (vending box) and change the selection before the payment. After checking the list of ordered items, agree with the payment; a payment QR code (containing account number information and total amount of money) is issued. After payment, the customer gets delivered items, and the customer should count the items before leaving. The system can be installed with cameras to support customers when problems occur, such as delivering more items, missing items, or wrong items. By integrating the QR code into the automatic transport system, the system could overcome the problem of reading denominations and returning change.

5.3. Discussion of limitations, failure occurrence, and troubleshooting of the proposed system

The proposed system has many advantages; however, it still has some drawbacks, such as the system not having a returning function in case of a wrong purchase (we could call customer service for help) and the large investment cost for the system of transporting items from the shelves to the customer. This transport system includes many auxiliary conveyors, main conveyors, motors, sensors, and other actuators; in addition, the control module needs a computer, a wifi connection, and software, as well as online payment costs for the banking system. However, these costs will be a small proportion of big revenues and profits when the large number of items are sold. The experimental study was conducted on a testbed, which is a miniature version of the real system, so there are still some limitations, such as the layout of the system being still confined in a box like the traditional vending machines.

When an automated system has been operating, some errors would arise, such as sensor failures, conveyor belt stuck, motor failure, overload system, transaction suspension due to slow network, network failure, wrong item delivery, excessive delivery, or lack of items. In this case, the staff will handle them with video from the camera or when receiving the calls of the customers. In practice, the system is necessary to go through a process of assessing the probability of failure with a suitable error rate before commercial application. Furthermore, the system needs to be maintained, and some components are regularly replaced to prevent the risk of failure. Automation systems usually reduce human labor; however, to ensure continuous operation of the system, it still needs a supervisor. In our future studies, the above troubleshooting issues should be considered in the system design process to overcome the limitations and the possible failures of the current system.

6. Conclusions

This study presented a new system for purchasing items at mini-marts with the integration of non-cash QR code payment technology. The proposed system helps to automate the purchasing process, automatic payments according to the worldwide cashless trend. Advantages of QR code payment make shopping quick, easy, time-saving, safe, and cashless. Overcoming existing limitations of previous payment technology using coins, cash, RFID cards, and GSM. The results of research and testing of the

device in the form of a demo demonstrate the usefulness of the proposed solution and the reliability of the transaction.

The integration of QR code with the automatic transport system at mini-marts, medium, and large supermarkets has not been widely researched in reality. The method of payment is the most difficult thing in automatic selling systems. Thanks to QR code payment technology, the problem is completely solved. The smartphone applications for purchasing items, scanning QR codes for payment, receiving ordered items at home, or taking those at the mini mart counters will have developed in the future. In addition, this solution can be applied in the automatic parking systems. The difference between this solution and ATMs, automatic beverage vending machines, automatic ticket vending machines, etc., is that it is able to automate mini-marts (even supermarkets) with many items, to integrate QR code payments to solve the limitations of vending machines such as limited item volumes, money reading modules, limited denominations, etc.

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Conflict of Interest

The author declares no conflict of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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