International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-8 Issue-4, November 2019

Self-Service Checkout System for Groceries

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Abstract*: Self-service checkout systems allow shoppers as active participants into a retailer's business processes. This paper focused on the development of electronic payment in groceries using Near Field Technology. This was done with the use of Radio Frequency Identification (RFID) cards which will replace cash outs and other online-based transactions that are prone to system failures. Several tests were conducted to determine how the self-service checkout system in this study will perform in real-world scenario. The transactions using the self-service checkout system can be finished in less than 41.13 seconds for five items and less. The test in the deduction of current balance by the system yielded 100% accuracy. In terms of security, the system does not rely only on video surveillance of a particular establishment because it has its own security mechanism that is enabled by a microcontroller. The security mechanism that matches the weight of the groceries calculated by the software program and the weight of the groceries weighed by the shopper yielded 100% accuracy during the testing. The self-service checkout solution in this study can provide a more time-efficient shopping experience to time-constrained users.

Keywords*: Self-service checkout system, Radio Frequency Identification (RFID) cards, Near Field Technology, Microcontrollers.

I. INTRODUCTION

In the present industry, modernization of retail store methods has improved market solutions to speed up the process of checking out grocery items. Stores and supermarkets have utilized self-service checkout systems to significantly hasten the shopping process. However, self-checkout solutions need a reliable payment method to make it hassle-free for shoppers. Failure or delay in making payouts could affect not only the current shopper but also other shoppers following the queue.

In order to solve these issues, recent studies and development have incorporated technologies to change the cash-based payment method on self-checkout systems. The most common payment method for self-checkout systems is using credit or debit card [1], [2]. This method, however, sometimes fails due to faults when online banking goes offline because of maintenance. This payment method is solely dependent on the Internet Service Provider (ISP) and reliability would be unpredictable which causes delay to the shoppers.

Another payment method that has already been implemented in a self-service checkout system is the mobile payment mechanism. This enables shoppers to pay the bill for groceries and other purchased grocery items in a store through the means of a mobile phone [3]. Unfortunately, this payment method relies heavily also on Internet connection which is still poor in some countries [4]. When a shopper is unable to connect to the Internet, using this kind of payment will cause a delay.

Considering the relative delay caused by the present method of payment in a self-service checkout system, a Near Field Communication (NFC) payment method was implemented in a self-service checkout system. NFC payment method was realized with the use of a Radio Frequency Identification (RFID) card. The RFID card is proposed to be secured by shoppers from a particular grocery establishment which is named in this study as an express card. This card is loaded with points in exchange for money to grocery management. The current points of the card and the identification of the shopper are stored in a database. This database is accessed locally by the self-service checkout system. This will remove the issues of connecting on the Internet to accessed bank services and mobile payment services. Moreover, the self-service checkout system has an improved security mechanism, something that previous self-service systems rarely have. This mechanism will add another level of security to the existing video surveillance of all groceries.

In this study, the time to complete the payment of groceries using the self-service checkout system was measured. The accuracy of the system in deducting the amount of the grocery items to the current balance of the card and the response of the security mechanism was also tested.

Manuscript published on November 30, 2019.
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II. MATERIALS AND METHOD

A. System Development

The system was composed of a barcode scanner, NFC card reader, Point-of-Sale (POS) thermal printer, and a microcontroller that were all connected to the system unit as shown in Fig. 1. A software application was installed to the system unit to allow the purchasing. The hand-held barcode laser scanner was used for scanning grocery items. The grocery items are displayed on the touchscreen Liquid Crystal Display (LCD).

The NFC card reader served as the module that reads the express card. The express card is an RFID card that is used by shoppers to pay their grocery items. When the payment is done, the system released a receipt through the POS thermal printer.

To complete the transaction, the shopper needs to weigh the grocery items in the weighing scale that is interfaced directly to the microcontroller. The microcontroller compares the total weight of the grocery items weighed by the shopper to the exact weight of the grocery items saved in the system. If the weights matched, the microcontroller activates the relay to switch on the electromagnetic lock so that the shopper can exit the purchasing area.

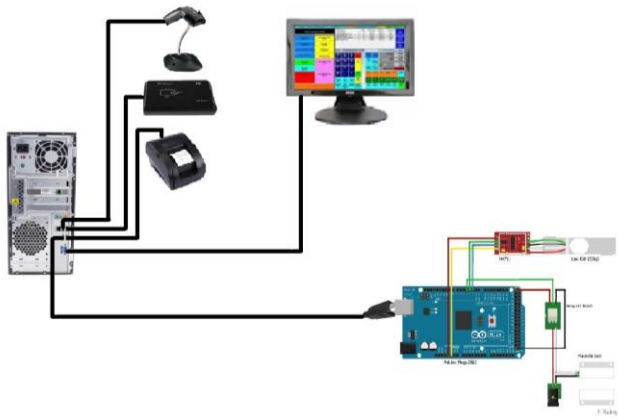

Fig. 1. Connection of the different materials in the system.

B. Security Mechanism

The security mechanism of the system was realized using an Arduino Mega 2560 microcontroller which is a general-purpose microcontroller [5]. This microcontroller was connected to the system unit via the USB port. It was programmed using the C-based language Arduino Integrated Development Environment (IDE). The Arduino microcontroller, as well as the IDE, is both open-source. It compares the weight of the groceries from the database to the weight detected by the weighing mechanism.

The weighing mechanism of the system was composed of a load cell and a load cell amplifier. The load cell shown is a force sensing module. The load cell was used in the self-service checkout system as a sensor to detect the weight of the grocery items. It was chosen because it measures a specific force, and ignores other forces being applied. This load cell was paired with the HX711 that throws digital value to the input of the microcontroller. The Load Cell Amplifier-HX711 is a 24-bit analog-to-digital converter (ADC). It was used to convert analog inputs into a digital value and was interfaced directly to the microcontroller. It was chosen to allow the system to easily read load cells to measure weight.

C. Self-service Checkout Software Program

The software program was developed using Visual C# programming language. This programming language is a high-level programming language that is used for building a variety of software program using the .NET Framework [6]. It was designed to be user-friendly to shoppers and was operational as touch input that suits for self-service checkout. The windows form for item scanning is shown in Fig. 2. There were two icons on the top left of the GUI, the shopping cart for the shoppers and the gear icon for admin users. The admin option was protected by a password. The textbox located in the center of the screen is where barcodes are entered. There was an option for manual encoding when the keyboard button on the left of the text box is pressed. A table is provided to display items which are scanned. The "Checkout" button enables the shopper to proceed to pay for the scanned grocery items.

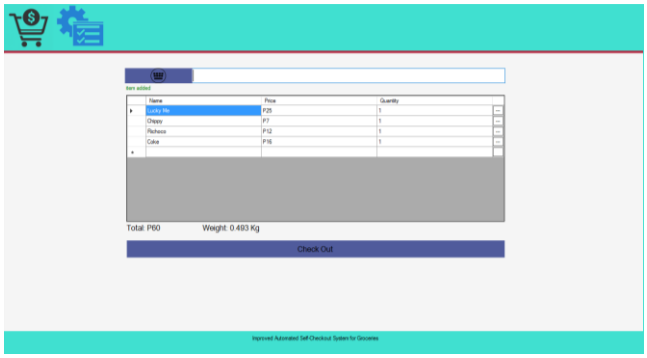

Fig. 2. Graphical User Interface (GUI) of the software program.

The windows form for payment interface is shown in Fig. 3. A shopper needs to swipe the express card and then press the "Proceed" button for the system to acknowledge the payment. The GUI design was forgiving because a "back" icon is provided to allow shoppers to go back to scanning if there are missed items.

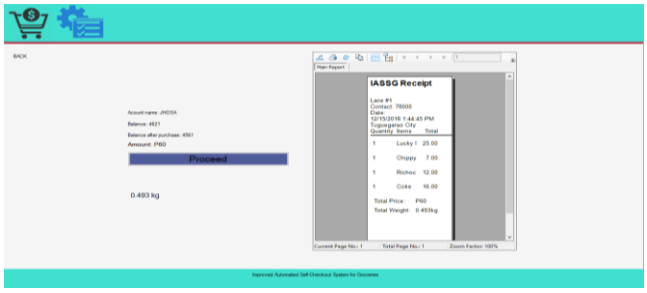

Fig. 3. Windows form for payment in the software program.

The GUI of the software program does not change much as customers move from one windows form to another. Only the attributes that change in the windows form but the background remains the same. This was done to bridge the gap between interaction and usability [7]

in a coordinated manner to create a consistent user interface design.

III. RESULTS AND DISCUSSION

A. Self-service Checkout System

The finished and functional self-service checkout system is shown in Fig. 4. The machine stands 63 inches in height, 24 inches in length, and 17 inches in width from its rectangular base. The machine and its railings were made to fit for an average person.

It was designed with a visual user interface on its front panel, scanners, and printer for receipts to resemble a complete cashier stand. A 10 x 24 inches aluminum table is provided for grocery items to be placed during the scanning and bagging for convenience before being placed to the aluminum weighing platform. On the exit door, there was an attached electromagnetic lock that secures the pathway before grocery items are held out of the shopping store.

Most of the components are held together into a laminated housing which is partially made of stainless steel on the front panel. The barcode scanner is attached to the aluminum platform on the front for easier access on barcode tag scanning. The touchscreen monitor was leaned up to 7 degrees as the standard viewing angle. The NFC card reader was placed on the right side of the LCD and below was the thermal printers which are lined up accordingly for payment transactions.

For weighing of the grocery items, the machine has an extended platform on the right side where the weighing scale was attached which consists of a 20 kg load cell and a square stainless-steel frame. Inside the machine is the microcontroller that was connected to the system unit via USB port. The magnetic lock was wired along the gate to lock the exit pathway.

Fig. 4. The self-service checkout system.

B. Testing the Self-service Checkout System

The time spent in checking out grocery items using the self-service checkout system developed in this study is shown in Table I. The use of RFID cards for payment drastically reduced the time spent on the whole checkout transaction with just swiping.

The minimal duration for checkout on average was 18.01 seconds for a single item checkout. For every additional item, it was observed that there was an increment of 2.64 to 8.60 seconds. The self-service checkout delivered a fast service which is required for every self-service checkout system as mentioned by Cho and Fiorito [8]. The NFC-based payment system simplified transactions which significantly reduced the checkout time when paying purchased groceries. This result agreed with the study of Bester and Bronkhorst [9] wherein NFC was faster on transactions at POS.

Table- I: Time Spent Checking-out Grocery Items

No. of Items	Time Spent (s)					Average (s)
	Trial 1	*Trial 2*	*Trial 3*	*Trial 4*	*Trial 5*	
1	18.29	16.26	18.35	18.5	18.67	18.01
2	28.83	21.30	29.39	25.24	23.04	25.56
3	29.00	28.11	31.11	29.42	23.37	28.20
4	30.00	34.18	36.25	39.69	43.87	36.80
5	40.88	44.96	42.79	46.20	30.80	41.30

Table II presents the capability of the system in calculating and deducting amounts from a user's account. The researchers made a separate computation on deducting the purchased value from the existing balance. For manual calculation, the researcher used calculator in computing the balance of the user after purchase. Accordingly, the system calculated value was the same as the manual calculation.

Table- II: Accuracy in Deducting the Purchased Amount

User	Existing Balance	Purchased Amount	Balance after Purchase		Remarks
			Manual	*System*	
1	1635.4	20.0	1615.4	1615.4	CORRECT
2	1615.4	27.0	1588.4	1588.4	CORRECT
3	1330.0	65.0	1265.0	1265.0	CORRECT
4	381.8	48.0	333.8	333.8	CORRECT
5	925.0	22.0	903.0	903.0	CORRECT
6	1588.4	46.0	1542.4	1542.4	CORRECT
7	1265.0	68.0	1197.0	1197.0	CORRECT
8	903.0	7.0	896.0	896.0	CORRECT
9	381.8	22.0	359.8	359.8	CORRECT
10	359.8	26.0	333.8	333.8	CORRECT

The correct calculation clearly suggests that the system was accurate in calculating the deducted amounts of purchased products. The use of NFC for payment system was an effective way to simplify shopping transactions without carrying cash and this method was more effective than credit card and online banking. It conforms to the finding of Mukhopadhyay [10] that the most obvious instrument of a cashless transaction should be one that is easily acceptable to most and should not reveal the identity of the user and details about other financial information. Table III presents the response of the security mechanism on each check-out. Overall, there were 20 trials conducted. For the first 10 trials, the security mechanism of the system was tested for honest customers who scan all their purchased grocery items.

During this testing, the computed weight in the software program matched the weight detected by the weighing mechanism and the door unlocks for the customer.

For the next 10 trials, the security mechanism of the system was tested for dishonest customers who do not scan all their purchased grocery items. During this testing, the computed weight in the software program did not match the weight detected by the weighing mechanism and the door remains locked for the customer. This will allow the grocery securities to arrest the dishonest customer.

The weighing mechanism was a strategy to secure the transaction on the self-service checkout system. The goal for its inclusion was to eliminate theft. It can be an answer to the problem of external thefts that are not scanning all the goods they purchased. External or customer theft [11] is defined as theft from the selling floor while a store is open for business. Implementation of this feature heightens the security of the self-service checkout system.

Table- III: Response of the Security Mechanism

Trial	Computed weight by the Software Program (kg)	Weight Detected by the Weighing Mechanism (kg)	Response of the Security Mechanism
1	0.06	0.06	Unlock
2	0.09	0.09	Unlock
3	0.35	0.35	Unlock
4	0.41	0.41	Unlock
5	0.25	0.25	Unlock
6	0.65	0.65	Unlock
7	0.03	0.03	Unlock
8	0.41	0.41	Unlock
9	0.19	0.19	Unlock
10	0.50	0.50	Unlock
11	0.06	0.08	Lock
12	0.22	0.28	Lock
13	0.52	0.60	Lock
14	0.12	0.38	Lock
15	0.31	0.35	Lock
16	0.33	0.37	Lock
17	0.13	0.32	Lock
18	0.44	0.49	Lock
19	0.57	0.39	Lock
20	0.19	0.26	Lock

IV. CONCLUSION

This study dealt with improving the quality of self-service checkouts by reducing the time spent and making a simple yet secured self-checkout transaction. The system speeds up the checkout process using the NFC payment method. Moreover, the system was proven to be precise and reliable in handling checkout payments. The security is strengthened with the addition of a door lock unit that responds accurately as intended. The system can be improved further by utilizing a mechanism that will automatically bag items after being weighed, and an alert notification for admin that will inform them for shopper assistance if needed.

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