IoT-Based Automated and Contactless Shopping Cart During Pandemic Diseases Outbreak

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Abstract. Coronavirus (COVID-19) is an alarming disease outbreak that has affected more than 180 countries worldwide. It has caused close to 2.5 million deaths and has infected 114 million of the global population as of February 2021. This unprecedented pandemic, has caused severe socio-economic problems globally, catching many sectors off-guard and in a state of suspended uncertainty. While vaccines are just starting to circulate, there is still a need to practice new social norms, including social distancing during daily activities such as supermarket shopping. As such, contactless technology is critically needed and preferable to minimize physical contact and mitigate virus spread. In this paper, an automated shopping cart is proposed as a potential solution to avoid item scanning at cashiers and long queues at payment counters. This innovation leads to reduced risk of exposure to COVID-19. This is done by integrating a typical shopping trolley with Internet of Things (IoT) technology. A radio frequency identification (RFID) tag is attached to every product and automatically read whenever they are placed in a shopping cart. Payment and weighing processes can be conducted at the trolley itself which reduces direct and prolonged contact with both cashiers and other patrons, and at both checkout queues and weighing counters. This proves to be a critical way to break transmission chains.

1. Introduction
COVID-19 has resulted in most socioeconomic sectors being severely affected across many countries. Many stores and malls are closed or are at reduced operation as a result of the outbreak. This has led to a tremendous increase in online shopping for daily items. However, consumers still prefer to shop for groceries and fresh foods physically and directly due to the need to maintain freshness of the products, and because of urgency. Online shopping and delivery may take days which is inconvenient and may damage the final product. Traditional retailers are struggling and need to open their stores to survive. An analysis by Retail Group Malaysia (RGM) shows that 61% of total retail outlets were closed for six-weeks [1]. Subsequently, the health and safety of staff and customers should be the main focus of operation while emphasizing hygiene levels. As the virus can easily spread via human interaction, shopping experience and delivery of goods should be done with as minimal contact as possible.

A study on frequency of shopping at a supermarket in the United Kingdom in 2015 shows that up to 56% of the respondents would still like to shop at the supermarket once or twice per week [2]. Traditional shopping requires that in most supermarkets, customers have to queue at payment counters to make payment. In addition, products that require weighing and packaging will require another long queue, especially during festive sessions and the weekends. As queuing takes time and increases the risk of infection, the need for an automated shopping system is critically needed. Even though some outlets allow convenient self-service shopping, the act of queuing for the self-scanning machines remains an issue. In worst-case scenarios, some counters may not even be open, leading to even longer wait times.
and elevated exposure risk. Opening all available counters may also not solve the long queues if cashiers still need to scan items and if there is a surge of customers (for example, during peak periods).

In this project, an automated shopping cart using an RFID reader and IoT is proposed to replace traditional shopping carts. This provides a shopping experience to customers that reduces infection risk by avoiding long queues and enabling social distancing while shopping.

2. Related Work

Research on developing a smart shopping cart have attracted significant amount of attention from researchers over the years. The following subsections discuss several shopping carts available in the markets.

2.1. Radio Frequency Identification

Most of the works found in literature are using RFID to scan items and solve the long queue problem. A smart shopping cart with automatic billing system through RFID and ZigBee was proposed in [3, 13]. After each scan, the data will be stored in EEPROM and send to database. In this method, customer just needs to make payment through credit or debit card. In another method, a smart shopping cart is proposed by [4] which is similar with the previous method. Besides that, an IoT technology on developing a secure smart shopping system is proposed in [5, 15]. Besides using RFID to scan items, quantity of the products on shelves are also monitored. However, the RFID needs to be charged for every new customer. A cashless method is introduced in [6] which is known as RFID-Cloud Smart Cart System. In this method, every customer needs to have a member card with credits for payment. The system will automatically deduct the credit after finishing by pressing a payment button.

Some other authors have also developed an interactive kiosk cart using Wireless Sensor Node [7]. This method provides a web portal for shoppers to search for product’s details and will receive the bill through e-mail or SMS after finish. This method is paperless and user-friendly to the environment. Nevertheless, customers need admin approval in order to make payment. On the other hand, B. Bhunkar et al. [8] proposed an automatic billing trolley using RFID and ZigBee with android application rewarding system. This project adds an extra feature for which customers can create an Android app for the rewarding system provided by the store. However, this system is only limited to Android users. Some authors have also proposed a smart shopping system utilizing Li-Fi technology [14].

2.2. Near Field Communication

Near field communication is another method in assisting smart shopping. A method for m-Commerce shopping using NFC is proposed by J. Dave et al. [9]. In this project, a smartphone with NFC function is used to buy desired products. Customers just need to scan the products using their phone and edit the shopping basket anytime. For payment purposes, customers will have to scan their smartphone for billing at counter which requires no physical trolley.

A Smart Billing System using Raspberry Pi and RFID has been proposed by M. Cherian et al. [10]. This system embeds IR sensor into the system in order to calculate the number of items that have been put into the cart. If the shopper tries to put items without scanning, the exit door will not be opened for customers to leave. The system will compare the number of scanning with the number of items put into the cart. However, the IR sensor will add up the number if customer accidentally put the products too near to the sensor. Some authors are also using face recognition to create an account for the first time and the user data will be saved in database.

2.3. Robotic Shopping Cart

A robotic shopping cart for shopping assistance is proposed in [11]. The shopping cart having self-returning function after customer log out from the system. It also contains the laser scanner to detect obstacles but it will stop until the obstacles do not block its way. On the other hand, a method is introduced for intelligent shopping cart with quick payment based on dynamic target tracking by X. Liu et al. [12]. The shopping cart contains visual target tracking and movement control which will follow the shopper. This let customer feel comfortable without pushing the trolley all the way.
3. The Proposed System

Considering some limitations of existing work, the proposed system avoids queuing at payment and weighing counter by introducing a contactless smart shopping at the shopping cart itself. Not only that, this system is also equipped with budget monitoring which is essential for daily spending. The proposed system can be divided into 3 phases: (i) Self-Scanning and Checkout Machine (ii) Pricing and Budget Comparison (iii) Integration with IoT. System overview and project design can be shown in Figure 1 while the overall system prototype can be found in Figure 2.

In this project, Arduino Mega is used as the microcontroller which represents the main brain of the system. All customers are provided with a member card consisting of customers’ information, as well as credits for purchasing. To begin shopping, customers just need to scan their member’s card and the information will be displayed on LCD screen. The LCD is used to show the information related to the shopper such as the ID and the remaining credits. The LCD can also be used to display information of the scanned products. Customers can also add items based on weighing category. To remove some items from the cart, two options are available: (i) take the items out by scanning it again and delete the item from the system or (ii) enter the weighing code to delete using keypad.

After each scan, the system will check the total amount and compare it with the current credit so that it will not exceed the limit more than the available credits. If total cost exceeds the remaining credits, the system will alert and immediately notify the customers using the attached buzzer. In such scenario, customers can decide either to proceed or remove some items from the shopping cart. Upon agreeing to proceed, customers need to top-up their credits immediately. After the decision, the latest information will be uploaded to Firebase database for records. These records will be summed up for total amount so that customer can directly proceed to payment by pressing the ‘payment’ button without having to queue at the counter.

Block diagram of the proposed automated shopping cart is shown in Figure 3(a) while project structure and phases is illustrated in Figure 3(b). Basically, the system consists of several parts which are scanning and weighing, add and remove items, top up and pay and the output modules. The RFID reader is placed on the shopping cart facing forwards and connected to Arduino Mega. The code that is registered inside the tag on products will be sent to Arduino Mega once the product is scanned. Based on the code, the microcontroller will retrieve data from the Firebase regarding the item’s name and price and display it on the LCD screen. The weight sensor is placed on the flat surface to get accurate readings of items that require measuring whenever placed on top of it. The price of products will be shown after customers enter a specific code number and getting the price per kg from the database. In addition, a keypad is attached on each cart to prompt input from customers.
3.1 Phase 1: Self-Scanning and Checkout Machine
A Self-Scanning and Checkout Machine is set up by connecting the Arduino Mega board with RFID reader and the weight sensor. The system starts by customer login into the system which then require them to select preferable functions: scanning or weighing using the attached keypad as shown by the process illustrated in Figure 4. All the sensors are installed accordingly to enable items scanning by users. The machine is also configured to allow price detection using RFID tag and the products weighing as shown in Figure 4. Regardless of scanning or weighing, price comparison will be automatically conducted upon each process. This allows customers to plan their budget for a particular shopping. Then, the system requires customers to scan their member card which will then show their details and remaining credits. The instruction can also be visualized by the customer in the LCD screen as shown in Figure 6(a). Moreover, customer’s name is displayed with remaining credits of RM50.00 as shown in Figure 6(b). As customer starts shopping, total spending amount will accumulate over time.
3.1.1 Items Scanning Module
The scanning function is used for scanning products as shown in Figure 6. After RFID scanning function is chosen, customers can just start scanning their preferable items (i.e milk or biscuit) using the RFID reader and put the items into the shopping cart. Upon each scan, information such as name and price of the item will be shown on LCD screen as illustrated in Figure 8(a-d). Upon each scan, the total amount will be updated on the LCD screen as well as in the system. The figures indicate that the items are successfully added into shopping cart and the total amount spent is updated. If customers change their mind to remove some items, they just need to remove the item from shopping cart by scanning the same item again.

3.1.2 Weighing Module
For testing purposes, weighing function is only limited with two items (fruits and vegetables). This could be extended with any items later. Customer wishes to buy vegetables or fruits can select the weighting function on the keypad.

Next, the system will prompt customers to key in a specific code of the item which will then show name and price per kilogram (kg) on LCD screen. Detail process of this module is shown in Figure 8. The chosen items need to be put on the weighing scale (embedded with weighing sensor) in order for the weight to be detected. When the weight of items is confirmed, customer will have to press ‘enter’ button on the keypad and the price based on the weight will be added and updated in the total amount cart. Using this weighing feature at each trolley will avoid human contact and waiting queue at the weighing counter. This can be done by entering specific codes for different items. For instance, ‘100’ is the code for Apple as shown in Figure 9(a-c). All the codes need to be declared in database and all customers can check the codes provided in the rack/isle. As soon as the customer puts the item into weighing area, the system will calculate the price based on the weight of that item.
3.2. Phase 2: Pricing and Budget Comparison Module

This stage involves the calculation of total amount and budget comparison as shown in Figure 7. In this stage, mathematical calculation is developed using the C/C++ language in the Arduino IDE. The calculation involved in this system include the addition/subtraction, multiplication/ division.

Over the time, the system will start to compare the total amount with the balance in the member card. Once total amount exceeded the total credit, a buzzer will be automatically turned on to alert the customer. Customers then are given a choice as to top-up their credit or remove some items from the cart as shown in Figure 9(d). Subsequently, customer can choose to end shopping or continue as they wish. If they wish to continue, the same process will start over again, or else, they can make payment directly by pressing the ‘payment’ button on the cart without queuing at counter. The system will start to check whether there is enough credit to make payment. If there is enough credit for payment, it will automatically deduct the credit from the card or else, the system will show “Insufficient Credit” and continue to alert customer to top-up or remove some items. It is worth to note that the payment can be made at the trolley itself, and this is very convenient and safe to be practiced during the pandemic period.
3.2.1 Top-Up Module
This function requires customer login when they wish to top up their credit. This is important for security purposes. After correct authentication, the system will request the amount to be top-up as shown in Figure 10(a). If the top-up successful, “Top Up Success” will be displayed on the LCD screen as shown in Figure 10(b) and an email containing the receipt will be sent to the customer’s registered email as shown in Figure 11. After the customer enter their password, they need to specify the amount of credit they want to top up. The ‘C’ button can be used to clear the wrong value if customer accidentally enter the wrong amount or else, the “#” button on the keypad can be used to proceed.

![Figure 10. (a) Enter top-up amount (b) Successful top-up](image)

3.2.2 Payment Module
In order to make payment, customers are required to press ‘D’ button at the keypad attached at the trolley as shown in Figure 12(a). Customers can also choose '*' to continue shopping again and '#' to confirm payment. Figure 12(b) indicates the successful payment.

![Figure 12. (a) Payment process (b) Payment successful](image)

Apart from showing the messages on the LCD screen, an email notification as shown in Figure 13(a) will also be received by the customer upon successful payment. The email specifies the total spending and the credit balance for customer’s future reference. In this project, this is completed using Blynk notification system which is linked to the customer’s registered email.
3.3. Phase 3: IoT Integration Module

The proposed system is integrated with IoT to enable data monitoring in the cloud and subsequent actions implementation. In this project, Firebase is used as online database to store the information of the customer and the products in stores. The sensed data will be sent and retrieved between the microcontroller and the database to provide information to customers, as well as for triggering actions. After customer finish shopping, the database will be updated and shown in Figure 13(b).

![Email sent after successful payment](image)

![Customer Data Updated in Firebase](image)

**Figure 13.** (a) Email sent after successful payment (b) Customer Data Updated in Firebase

4. Conclusion and Future Work

Automated Shopping Cart is the proposed project that is invented to replace the traditional method of shopping to be used during pandemic of Covid-19. This project not only eliminates the long queue problem at payment and weighing counters, but also avoids human contact and interaction which is the main cause that can spread out the virus. This project is using Arduino as a microcontroller together with NodeMCU. The Arduino is used to control the sensors and NodeMCU is used to link the shopping cart with online database (Firebase). Every item with tag is registered in the Firebase so the items can be scan directly at the trolley to be added or removed from the shopping cart. Customers are also able to weigh items at the trolley without queuing at the weighing counter. The information such as the name and price will be shown on LCD screen. Not only that it provides safety and touchless measures that are important to break the chain of Covid-19, customers are also able to managed their budget by receiving alert upon exceeding credit limit, which highlights additional feature of the project. Payment can also be made at the trolley itself without having to queue at payment counters which is more convenience in ensuring customers’ safety.

Even though this project had achieved the aims and the objectives, there are still rooms for improvement that can be done in the future research. First, an RFID scanner with anti-collision algorithm can be used as a checkout point in the supermarket. This can reduce the cost to implement an RFID scanner on every trolley as it can read multiple tags that stack on each other. Besides that, touch screen display can also be added into shopping cart so the customer can check promotion, ingredients or details of an item. A navigation system can be implemented to navigate customer to the place that item sell which can help them to save a lot of time to search one by one. Lastly, a recommendation list can be introduced in this shopping cart. The Item-to-Item Collaborative Filtering will match every user purchased and rated items to similar items. The algorithm will create a similar items table to find the items that customers have a tendency to purchase together. By building a Product-to-Product Matrix to repeat all the item pairs and computing a similarity metric for each pair.
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