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Design and Implementation of Smart Shopping Cart Based On Web Application Technology

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ABSTRACT

Due to waiting time in cashier queues, resulting in a decline in consumer satisfaction and loss of precious time. Because of this problem, we proposed the solution for reducing waiting time in the cashier queue is a tool that can identify the type of retail product and the quantity that customers will be purchasing. In creating the design, Blender is used for the 3D, and Figma is used for creating User Inteface (UI). Hardware implementation using Jetson NANO microcomputer with camera modules to capture products and Wi-Fi capabilities to enable seamless cloud integration with its web application. Implemented in parallel with hardware implementation, the software implementation focused on creating a web application that displays every product that enters the Smart Cart. A combination of sensors, wifi modules, and a microcomputer ensures optimal performance for data handling with the database. The approximate round trip connection to the database has a minimum time as small as 17ms while the maximum is 57ms and the average is 23ms.

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1. Introduction

People frequently go shopping as part of everyday routines. However, as more people shop at the same supermarket, there will be congestion at all peak hours. The primary source of congestion at the supermarket is an excessive number of customers relative to the number of cashiers available. Due to waiting time in cashier queues, resulting in a decline in consumer satisfaction [1] and loss of precious time [2].

Based on a customer satisfaction survey given to 155 individuals in Bandung, Indonesia, 53,5% of the respondents said they have to wait in long lines at cashiers while they shop. Modernized payment and queuing systems were cited by 71% of respondents as the best way to increase consumer satisfaction when shopping. From the results of the survey, most of the respondents wanted a new and more efficient way to pay when they shop.

According to research conducted by Mykoniatis in 2020, “self-checkout” is a method to reduce waiting time in cashier queues [3]. However, this strategy requires the fulfillment of an ideal condition to attain the main purpose of reducing waiting time in cashier queues. The stated ideal situation is one in which every consumer is proficient in using the "self-checkout" feature and there are no mistakes or systemic fraud. On the other hand, putting this strategy into practice may cause problems like lowered customer satisfaction when problems arise [3] and security gaps that allow customers to commit fraud.

The use of a Radio Frequency Identification (RFID) tag on each retail item sold in a supermarket is a method to reduce waiting time in cashier queues. RFID reader is installed on each shopping cart to read information about every retail product that gets put inside the cart. The information about the products is then calculated by computer and the customer can pay according to the total [4]. However, this method required a large amount of money and resources. The reason is that every product sold needs an RFID tag which can lead to higher production costs and also can make prices go up.

The solution for reducing waiting time in the cashier queue is a tool that can identify the type of retail product and the quantity that customers will be purchasing. This tool can then automatically calculate the entire cost of the products in real-time and facilitate an integrated payment process. The customer then can pay with ease and proceed to leave the store without getting in a long cashier queue.

The contributions of this paper are as follows:

1. Designing a smart shopping cart system that consists of both hardware and software.
2. Implementing a hardware solution with camera sensors and deploying a web-based application by leveraging the Flutter framework.

This paper consists of five sections, the rest of which is section 2 which describes the literature reviews. Section 3 describes the proposed method of the research, while section 4 describes experimental results and analysis and lastly section 5 gives the overall conclusion of the research.

2. Literature Review

This section discusses research conducted by other academics that attempts to address the issue of cashier queueing time. There are two notable research on this problem, each with its own benefits and drawbacks. The two notable solutions are: 1) self checkout system, and 2) RFID-based shopping cart.

2.1. Self Checkout

One of the possible solutions based on research that can improve efficiency of shopping is self-checkout system. This mentioned solution has been researched and well-documented. Self-checkout [3] is a good solution to reduce operational cost of a retail store significantly. This mentioned solution has a bigger security loophole than a conventional cashier system. This solution also has limitations where the user has to know how to operate the self-checkout cashier which can lead to a longer queue than normal cashier.

2.2. RFID Shopping Cart

Another research on creating a smart cart is RFID and mobile application-based [4], [5]. The RFID reader is implemented to read the information of a product when it enters the shopping cart. The mobile application will display the list of products, their prices, and total payment. The user can choose to pay for their groceries directly through the app or by using any other preferred method.

Although this method has benefits, such as reducing cashier queuing time, it has a significant flaw in its design: every item that needs to be integrated into the system must have an RFID tag to store product details. This produces a significant increase in implementation cost, not to mention the amount of additional plastic wastes will be produced. Another flaw in its design is that this solution is counterintuitive: it will add additional waiting time due to the need to detach RFID tags from the products.

3. Proposed Method

This section will describe the method of design and development of the Smart Cart and its web application. The steps in designing and developing will be broken down into three sub-sections, starting from mockup design, hardware implementation, and web application implementation. The next sub-sections will discuss the methods mentioned earlier.

3.1. Mockup Design

The design step is the initial step before real-world implementation, this step focuses on the visualization of the proposed concept and gives a better understanding of the challenges that are about to come. In creating the design, Blender is used for the 3D design of the Smart Cart for it is an open-source application with ready-to-use plugins.

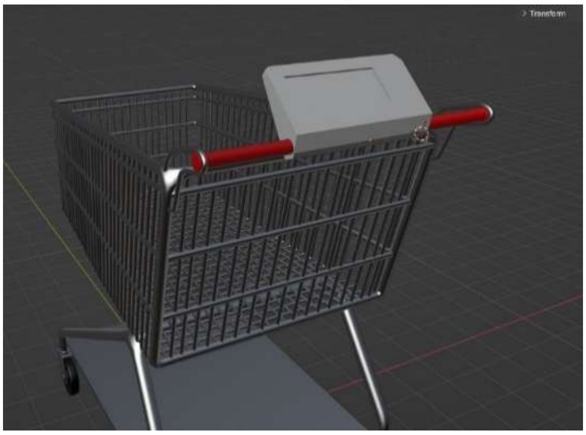


Figure 1 3D Design of The Cart

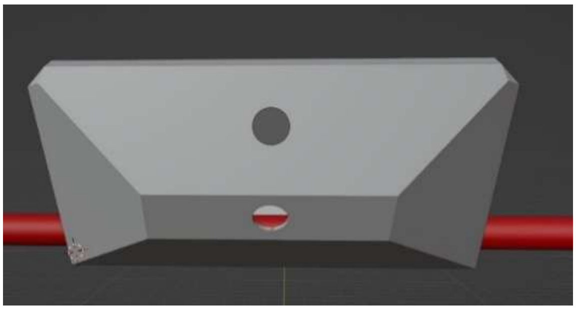


Figure 2 A Closer Look at The Camera Port

Figure 1 looks at the initial design of the Smart Cart, Figure 2 takes a closer look at the camera port, where the two cameras will be placed. Meanwhile, Figma is used for creating UI designs for the same reason as prior. The design of both hardware and software must follow a philosophy of being aesthetic while keeping its ergonomic values.

3.2. Hardware Implementation

With the hardware mockup design finalized, the next step is to transition to the hardware implementation step, translating the prior design to a tangible prototype. The hardware architecture comprised a 3D printed chassis made with ABS+ filaments and equipped with a Jetson NANO Microcomputer with camera modules [6] to capture products and Wi-Fi capabilities to enable seamless cloud integration with its web application as shown in Figure 3. Thorough testing and validation processes were carried out to guarantee the hardware components' dependability and effectiveness under varied operating circumstances.

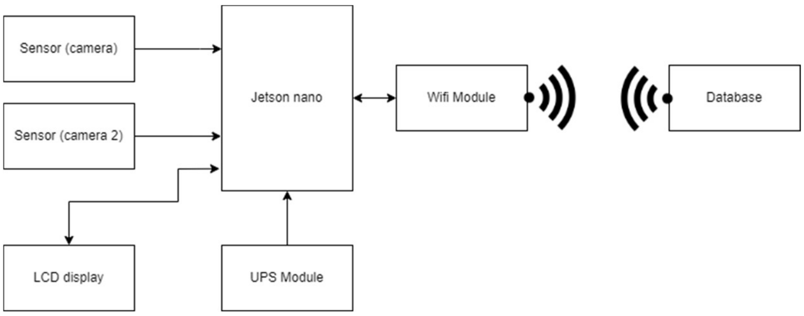


Figure 3 Hardware Block Diagram

The fitting of components inside the designed case requires multiple types of connectors. As shown in Figure 4 where Jetson is connected to a UPS power unit, dual camera using a 15-pin FFC and also connected to a WIFI module using an M.2 connector. Meanwhile, LCD connected via HDMI. Figure 4 also shows the real implementation of hardware design from the side, a close-up of the LCD panel, and its inside. Cameras that installed in this project is 77 degrees field of view that ensure minimum distortion by the lenses[7].

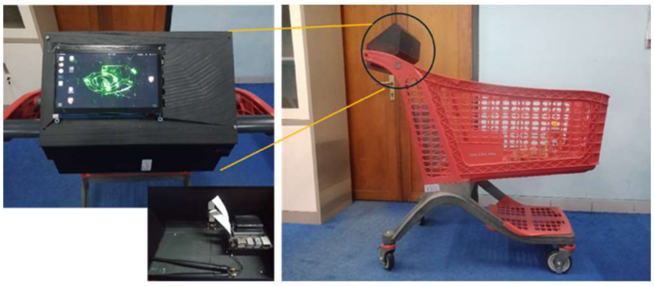
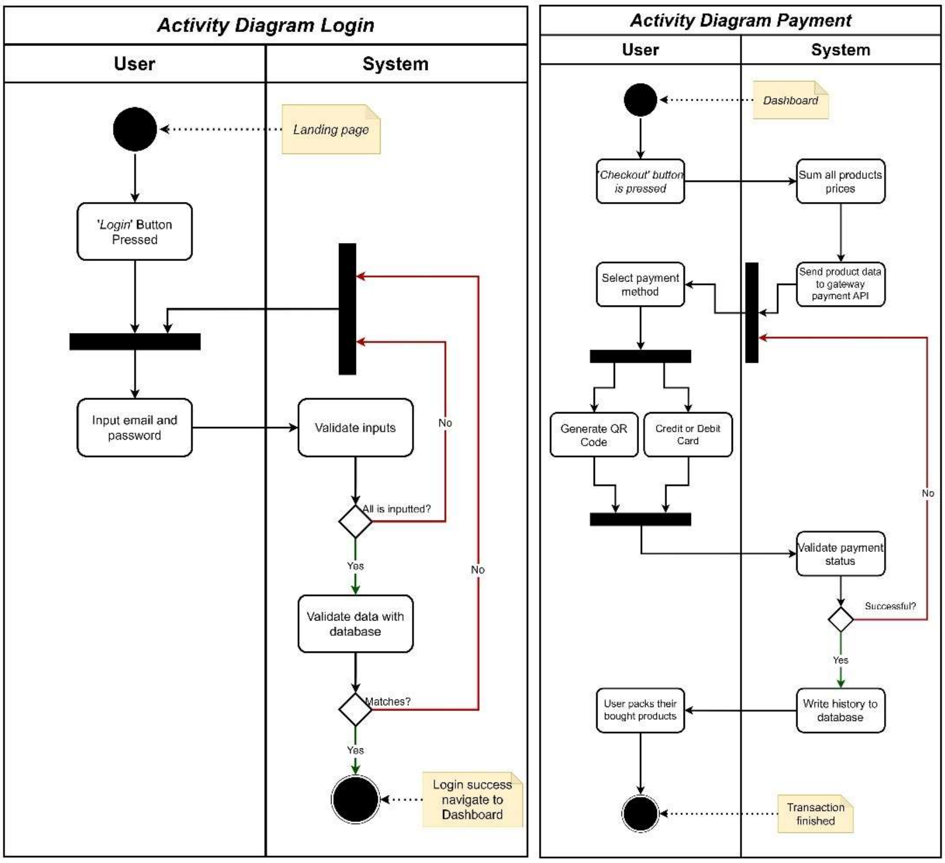


Figure 4 Hardware Design Implementation

3.3. Software Implementation

Implemented in parallel with hardware implementation, the software implementation focused on creating a web application that displays every product that enters the Smart Cart. Leveraging the Flutter framework[8], [9], an intuitive UI is created based on the prior design philosophy. Flutter's cross-platform capabilities ensure a consistent user experience across different devices[10]. Additionally, Firebase served as an authenticator as well as a backend database enabling real-time data synchronization between the cart and the web. The web also uses Xendit Payment API as a gateway payment for transactions and enables multi-payment methods[11].



(a) (b)

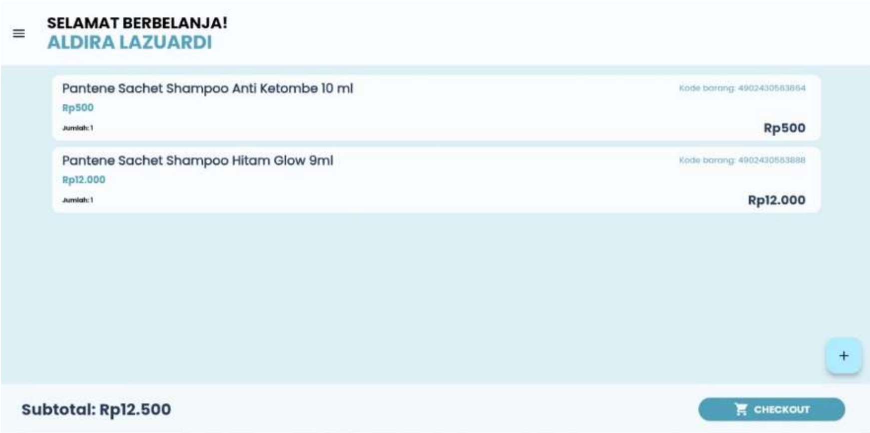
Figure 5 Activity Diagrams, (a) Login Activity Diagram and (b) Payment Activity Diagram

Thorough testing, including unit testing and integration testing, was conducted to ensure the robustness and scalability of the software solution. Figure 5 and Figure 6 show the diagram activity of the login and payment function, and the login page UI with dashboard UI respectively. Both of these function works in conjunction with who is currently logged in as a user or customer.

4. Experimental Results and Analysis

This section discusses the experimental findings from the Smart Cart system's implementation, with an emphasis on and microcomputer setup, resource utilization, computation time, client-to-server statistics. These measurements are crucial for assessing the effectiveness and performance of the suggested system.

(a)



(b)

Figure 6 UI Page Examples (a)Login Page UI and (b) Dashboard Page UI

4.1. Microcomputer Configuration

The microcomputer configuration of the Smart Cart system consisted of a Jetson NANO devkit with specifications including a 64GB microSD card, 4GB of RAM, a 300Mbps (2.4GHz 40MHz 802.11n) Wireless Network Card, two 8 megapixel camera modules, a 7-inch HDMI IPS display, and a 5V power supply that can last up to 5 hours of runtime. This combination of hardware modules ensures optimal performance for data handling with the database[12].

4.2. Computer Resource Utilization

Analysis of computer resource utilization revealed efficient utilization of system resources throughout the operation of the Smart Cart. Jetson's memory usage remains stable throughout, GPU usage is high whenever a certain function is called [13] but low otherwise, while CPU usage is stable on the lows, this indicates a correct utilization of computing power [14]. Complete information about resource utilization can be seen in Figure 7.

Client-to-Server Statistics

Client-to-server statistics focus on the reachability of the server hosting the web application. Figure 8 is the full report of the client-to-server statistics using ping from the command prompt. This test is condutcted based on the supposed reliability of cloud servers[15].

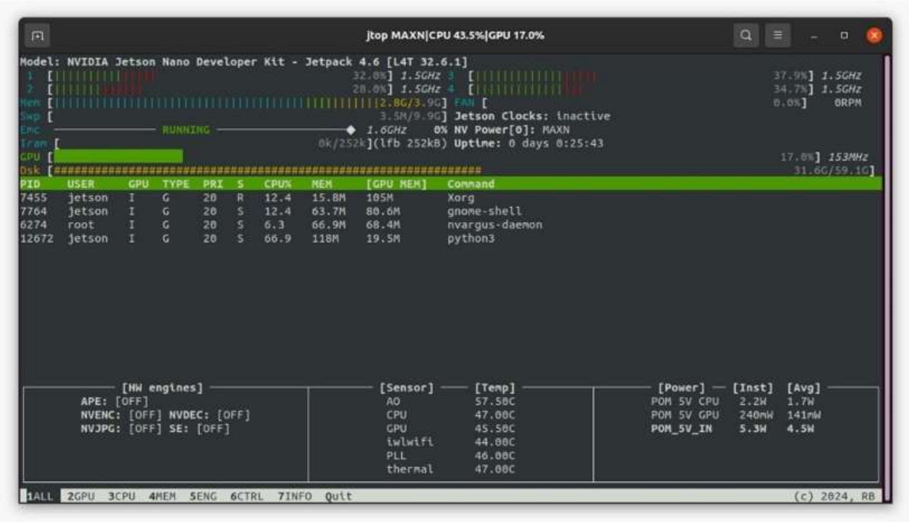


Figure 7 Usage Statistics

```
Pinging tubescc2023.web.app [199.36.158.100] with 32 bytes of data:
Reply from 199.36.158.100: bytes=32 time=57ms TTL=54
Reply from 199.36.158.100: bytes=32 time=23ms TTL=54
Reply from 199.36.158.100: bytes=32 time=18ms TTL=54
Reply from 199.36.158.100: bytes=32 time=24ms TTL=54
Reply from 199.36.158.100: bytes=32 time=18ms TTL=54
Reply from 199.36.158.100: bytes=32 time=18ms TTL=54
Reply from 199.36.158.100: bytes=32 time=20ms TTL=54
Reply from 199.36.158.100: bytes=32 time=22ms TTL=54
Reply from 199.36.158.100: bytes=32 time=19ms TTL=54
Reply from 199.36.158.100: bytes=32 time=17ms TTL=54

Ping statistics for 199.36.158.100:
    Packets: Sent = 10, Received = 10, Lost = 0 (0% loss),
Approximate round trip times in milli-seconds:
    Minimum = 17ms, Maximum = 57ms, Average = 23ms
```

Figure 8 Client-to-Server Statistics

In summary, sending 10 packets of data to the server is met with exceptional results, none of the packets get lost or declined meaning it has 0% packet loss. The approximate round trip has a minimum time as small as 17ms while the maximum is 57ms and the average is 23ms. The server is hosted in Taiwan with Firebase as its provider, this proves the reachability of the server is on par with what the systems need.

5. Conclusion

The Smart Cart is designed to improve shopping efficiency in supermarkets. In this day and age, shopping is part of the routine of everyone's life. This Smart Cart can minimize queues in supermarkets, especially the cashier queue. This is based on a survey conducted with 155 people in Bandung, Indonesia. 53.5% of respondents said that they had to queue long at the cashier when shopping. This Smart Cart consists of a combination of hardware and software systems. The hardware itself, such as a microcomputer, sensor (camera), and LCD, as for the software itself, is a web-based application. These things can support the functionality of Smart Carts properly.

In addition, this Smart Cart has several advantages, including Jetson Nano memory consumption that is stable every time it is used, and efficient use of the GPU every time it is used, which means that the system can detect and process an image properly and quickly. The process of sending data from client to server, has advantages too, as in the experiments that have been carried out, there are no failed connections, and the average data transmission speed is 23 ms. This can be considered excellent for supporting this Smart Cart.

This research is still very open to future improvements in various aspects. One area that needs enhancement is the issue of stacked items, which can result in a lack of detection by the cameras. Additionally, further development in detection technology can also be improved, such as camera lighting, noise reduction, and sharpness can also be improved.

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