# DESIGN AND IMPLEMENTATION OF A LIGHT FIDELITY BASED AUTOMATED SMART TROLLEY FOR SHOPPING USING RADIO FREQUENCY IDENTIFICATION

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## ABSTRACT

The Design and Implementation of a Light Fidelity based automated smart trolley for shopping using Radio Frequency Identification technology was aimed at reducing the time and efforts needed while shopping by customers. It is also used to reduce the long queues experienced. The methodology employed in implementing this system include the software and hardware integration, the software aspect of this system includes simulating the system performance on proteus and programming the Arduino Uno controller using C++. The hardware aspect involved integrating the components needed. The smart trolley, after implementation was able to display the different aisles in the supermarket, detect products or items placed in the trolley, display relevant information like price, date of expiry, weight, and also compute the prices of products or items as they are added. The system was designed to carry a maximum of 20kg load. Furthermore, the details of the items are transmitted to the cashier's system when the trolley is within a maximum distance of 6.0 meters to the cashier's end using the concept of Li-Fi technology where the final billing and payment takes place in order to clear customer for exit.

**Keywords:** Automated Smart Trolley, Arduino Uno Microcontroller, LCD, Li-Fi, Load Sensor, RFID Tags, RFID Readers, Trolley.

## I. INTRODUCTION

A scarce natural resource that is essential to all nations is radio frequency spectrum. The broadcasting and communication industries, as well as those in the fields of transportation, security, science, and recreation, all rely heavily on this resource. The limited amount of radio frequency spectrum is progressively reducing as a result of the explosion in communication technology options, which has increased global communications and necessitated the development of new spectrum-based communication methods [1].

A new technology called Li-Fi has developed in order to achieve greater bandwidth, efficiency, and speed. Light-based wireless bidirectional communication is known as Light Fidelity (Li-Fi). It makes advantage of the unused visible spectrum while easing the strain on the radio spectrum [2]. It can be thought of as an optical kind of Wi-Fi that transmits data through visible light rather than radio frequencies. With Li-Fi, we can utilize the visible spectrum, which has a frequency bandwidth of about 300 THz, which is significantly wider than the typical radio frequency band (RF), which has a bandwidth of 300 GHz and is constrained and steadily decreasing [3]. Three different high frequency technologies for communication networks are Ethernet, Wi-Fi, and Li-Fi. While Li-Fi technology uses light as a communication medium, Wi-Fi and Ethernet both use radio frequency waves [4].

These days, if a customer wants to make purchases at a mall, they must select the item from the display shelf, stand in queue, and then wait for their turn to pay the cashier. It will take a long time for customers to wait while those in front of the queue scan each and every item using a traditional barcode scanner. This is followed by the time it takes to complete the payment process [5]. To increase the quality of the shopping experience for customers, ongoing improvements to the current billing system are required [6]. An RFID system consists of three parts: an antenna, a transceiver (which is sometimes integrated into one reader), and a transponder (the tag). The idea of employing RFID technology will assist reduce the line and time spent or wasted by clients when shopping [7]. It is crucial to identify methods to enhance the shopping experience while taking into account variables like return on investment, anticipated sales growth, and customer expectations.

Subsequently this paper is organized as follows; section two discusses the review of past works, section three entails the methodology, section four presents the results and discussions, section five is for conclusion, finally section six covers recommendation for future work.

## II. RELATED WORKS

The RFID module and the ZIGBEE module were employed by the authors [8]; the former scans for product tags, while the latter acts as a transmitter to send data from the trolley to the main computer. Here, an AT89S52 microcontroller is employed. The system was put into place to streamline the billing procedure, make it efficient, and boost security utilizing RFID technology. However, weight sensors and online shopping cart payments were not taken into account, which would have enhanced the system's functionality.

The RFID reader in the smart trolley system will scan the product's price, name, and expiration date and display it on an LCD [9]. Cost information is transferred from the LPC2148 microcontroller in the RF transmitter to the LPC2148 in the RF receiver. This data will be sent from the receiver through serial transmission to the computer (Max 232 interface). The authors devised a system that uses the concept of RFID rather than barcodes to speed up billing and improve the shopping experience by mitigating the time wasted when making payments.

The authors of [10] used PIC microcontroller, RFID reader and tag, Li-Fi transmitter and receiver, LCD display, and Max232 logic converter to make up their system. The PIC microcontroller and RFID are interfaced. The main computer can receive product information from the PIC controller through a Li-Fi transmitter. The data can then be transferred to the computer using MAX232 serial transmission. As a result, the authors used Li-Fi technology to develop a system that improves the billing process by reducing the time utilized in scanning items with regards to barcode and also boosts security.

The authors in [11] designed a system so that when an RFID tag is read, the RFID module begins to operate and sends a signal to the microcontroller. The Li-Fi module and Li-Fi receiver module are also hooked to the microcontroller, which is connected to a power source that powers the cart. The customer receives information about the products that have been scanned and displayed on the LCD, while the voice board provides information about each product, the Keypad is used to choose between different trolley modes, and the parallax data acquisition tool (PLX DAQ) software is used to transfer the data to an Excel sheet via a Li-Fi module.

The work of [12], has the system connected to a WLAN network, where all product information is being stored. After shopping, the bill is sent to the database, and each trolley has a unique number. An employee at the billing counter scans this number, and item details are available for the customer to make an instant payment. The customer must scan products before placing them in the trolley; if they are not scanned, a load cell helps to alert that the product in the trolley does not correspond to the weight of items scanned. The LCD displays the products and prices. The system's design aids in shortening queue long wait at the bill counter in shopping malls. Additionally, the technology makes sure that every item placed in the cart is scanned and totaled up for invoicing.

## III. METHODOLOGY

**BLOCK DIAGRAM:**

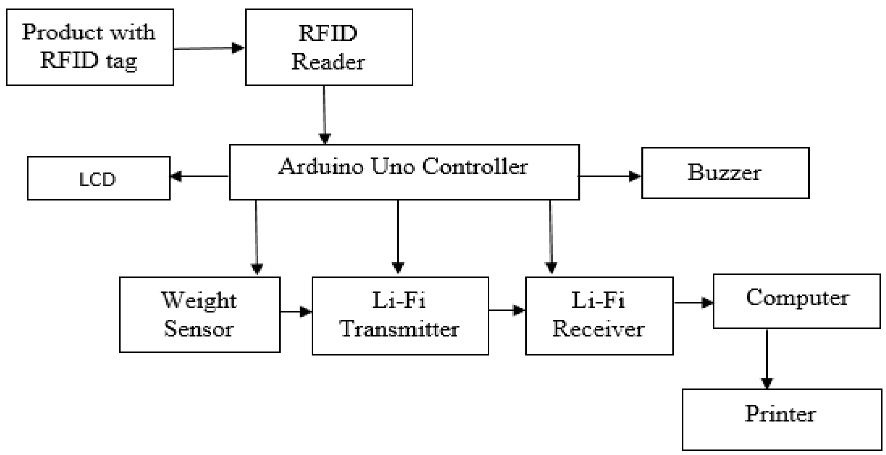


Figure 1: Block Diagram of the Smart Trolley System

The block diagram in Figure 1 depicts how the building blocks interacts with each other to yield the complete smart trolley system. The items will have RFID tags which is read by the RFID reader, information read from the RFID reader is forwarded to the Arduino Uno controller and is displayed on the LCD, the weight sensor helps identify weight of items placed in the trolley and as more items are placed, it keeps weighing the item, it also helps to reduce weight of items removed from the trolley. The buzzer helps with the sound while products are placed in to the trolley or removed from the trolley, Li-Fi transmitter and receiver utilizes wireless communication means to send information from the trolley to the computer. The Li-Fi transmitter is mounted on the trolley, while the Li-Fi receiver is at the cashier's end. The information of items placed in the trolley can be printed from the computer with the help of a printer which will then serve as the customer's receipt and clearance for exit from the supermarket.

The flowchart of the system software is depicted in Figure 2 which explains the working principle from the start to end.

For weight increased;

Let $W_n = \text{Initial Weight} = 0$ (1)

$W_t = \text{Total Weight}$ (2)

$W_t = W_{n1} + W_{n2} + \cdots W_{nx}$ (3)

Where "n" denotes items counts as they are added.

$n_t = n_1 + n_2 + \cdots n_x$ (4)

Let cost of items be denoted by "C"

Hence, $C_t = \text{Total cost of items placed in the trolley}$ (5)

$C_t = C_{wn1} + C_{wn2} + \cdots C_{wnx}$ (6)

Where $C_{wn1}$ is cost of the first item added with it corresponding weight

$C_{wn2}$ is cost of the second item added with it corresponding weight

$C_{wnx}$ is cost of the last item added with it corresponding weight

For weight Reduction;

$$W_t = W_{n1} \pm W_{n2} - W_{nx} \quad (7)$$

Where $x = 1,2,3 \ldots$

To decrease item selected count by 1,

$$C_t = C_{wn1} \pm C_{wn2} - C_{wnx} \quad (8)$$

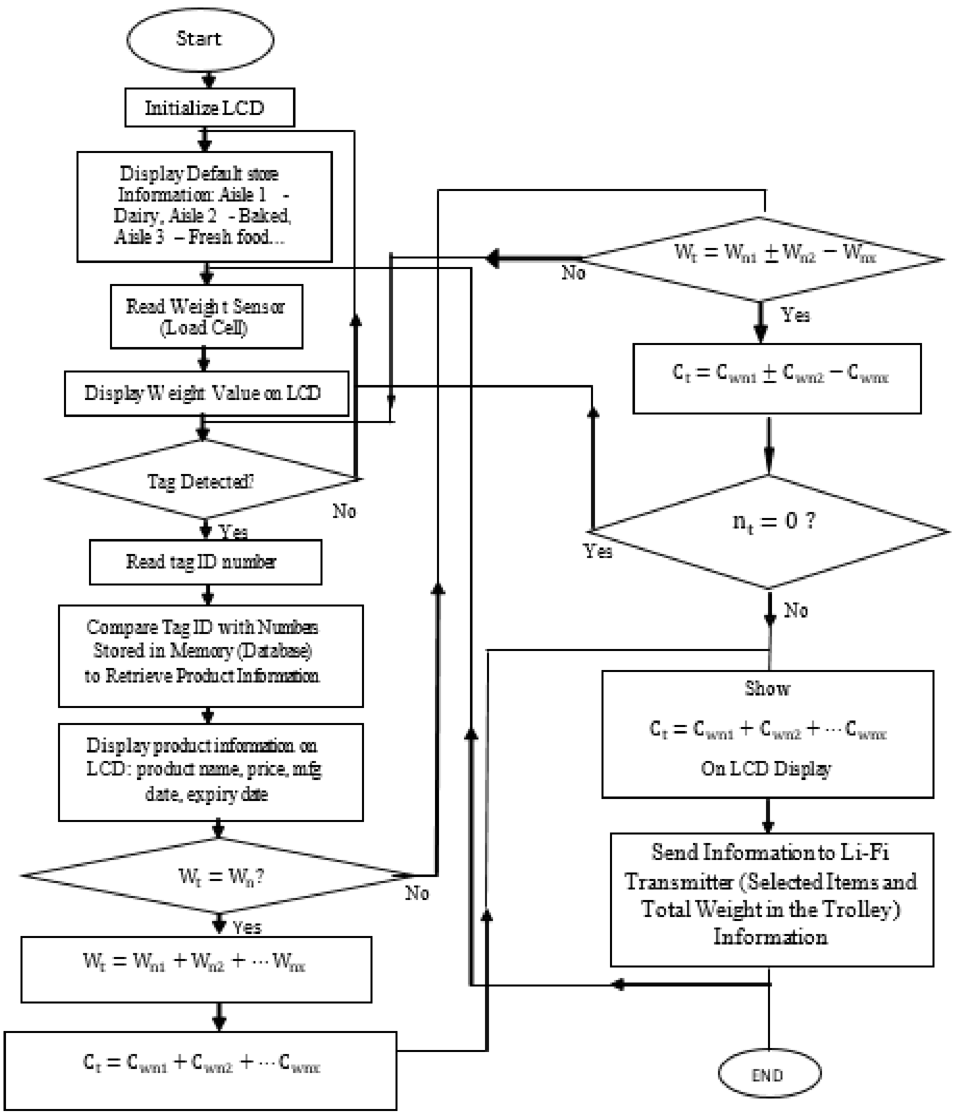


Figure 2: System Flow Chart of the Project

## IV. RESULTS

The design electronics components were cased so as to serve as a better means of integrating it on the trolley. The complete smart trolley is shown in figure 3, where ten items were placed in the trolley. All these items had their information displayed respectively on the trolleys display in order to convenience the customer while shopping.

Figure 3: The Complete Smart Trolley

The complete smart trolley having in it ten items is shown in figure 3. The information received by the Li-Fi receiver is displayed on the computer as shown in figure 4, the Li-Fi receiver module to be connected to the computer is shown in figure 5.

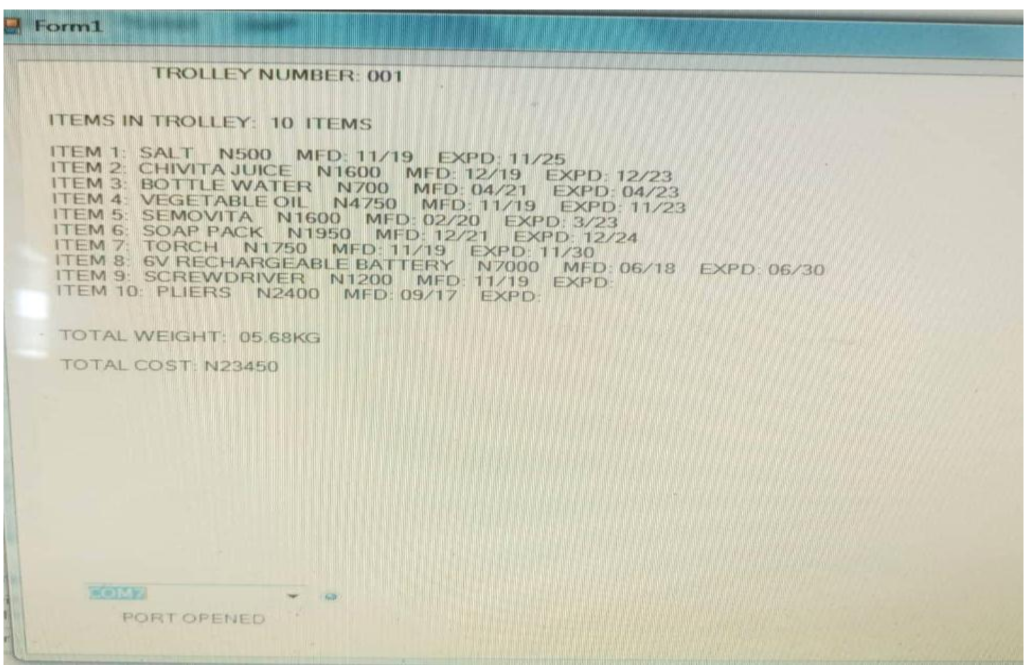


Figure 4: Cashier's Computer Display Showing Items in Trolley

Figure 5: Receiver Module interfaced with the computer

The systems behavior and results after successfully implementing the design was recorded. The findings were tabulated and discussions was made on each result. When the system is put ON, the 20x4 LCD displays "Li-Fi based automated smart trolley for shopping using RFID" thereafter displays "NDA EEE Supermarket" and the different aisles in the store as being programmed. Table 1 gives the tabulated result of the trolley's weight measurement feature.

Table 1: Trolley Weight Measurement Analysis

| S/N | Items | Actual Weight (Kg) | Trolley's Measured Weight (Kg) |
|---|---|---|---|
| 1 | Semovita | 0.001 | 0.001 |
| 2 | Torchlight | 0.1 | 0.1 |
| 3 | Chivita Juice | 0.11 | 0.11 |
| 4 | Screwdriver | 0.12 | 0.13 |
| 5 | Plier | 0.24 | 0.24 |
| 6 | Soap Pack | 0.32 | 0.33 |
| 7 | Salt | 0.5 | 0.5 |
| 8 | 6V Rechargeable Battery | 0.65 | 0.64 |
| 9 | Faro Bottle Water | 0.79 | 0.79 |
| 10 | Vegetable Oil | 0.93 | 0.93 |
| | Total | 3.76Kg | 3.77Kg |

The result from Table 1 was carried out using a standard weight meter to measure the items and compare with the trolleys ability to measure the items. The standard weight meter was calibrated to measure in gram by default, whereas the weight sensors on the trolleys measures items in kg. Items 1 and 2 from the table 4.1 had on them their weight from their manufacturers. These standard items were used in order to check the trolleys weight measurement accuracy. It is obvious that the trolley functions properly in identifying the weight of items placed in it. The 20kg weight sensors were implemented in the design to achieve this feature.

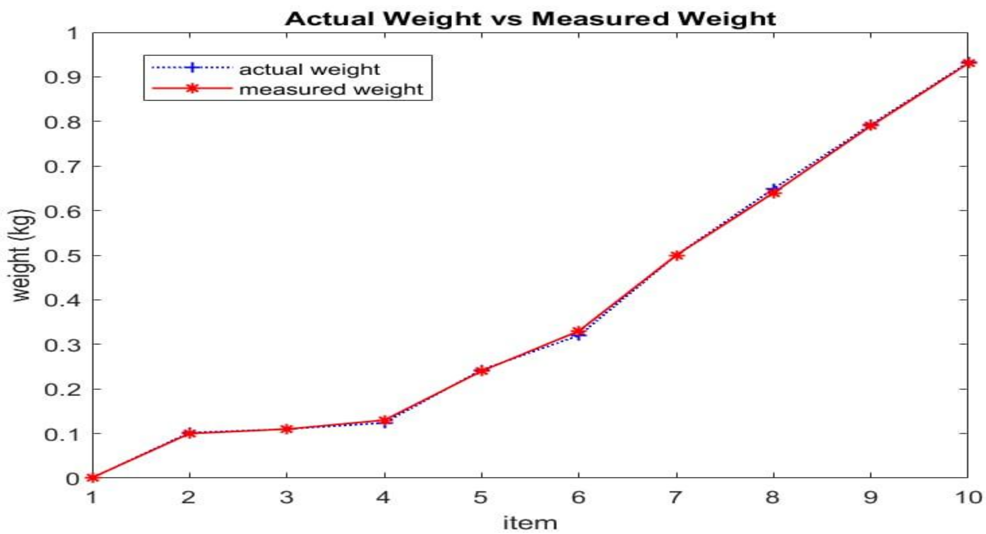


Figure 6: Graph of Trolleys Measured Weight in Comparison with Actual Weight of Items.

The graph in figure 6 shows the trolley's measured weight versus the actual weight of items in consideration, and it can be seen that the two plots closely corresponds to each other, so the trolley's measured weight is fairly accurate and could be relied upon.

The permissible operation distance of the whole system working was also tested (Table 2) and the result obtained is shown appropriately.

Table 2: Distance Performance of the Trolley System

| Distance Measured (m) | Data Recognition | Remark |
|---|---|---|
| 0.5 | ✓ | Data Reception |
| 1.0 | ✓ | Data Reception |
| 1.5 | ✓ | Data Reception |
| 2.0 | ✓ | Data Reception |
| 2.5 | ✓ | Data Reception |
| 3.0 | ✓ | Data Reception |
| 3.5 | ✓ | Data Reception |
| 4.0 | ✓ | Data Reception |
| 4.5 | ✓ | Data Reception |
| 5.0 | ✓ | Data Reception |
| 5.5 | ✓ | Data Reception |
| 6.0 | ✓ | Data Reception |
| 6.5 | X | No Reception |

The smart trolley system is capable of sending data to the receiver which is on the cashier's end if and only if the system is within 6.0m range. The items on the trolley automatically displays on the cashier's computer, thereby informing on the items in the corresponding trolley. The IR LED which transmits the data from the trolley have light emitting angle of approximately 20º to 60º and range of approximately 6m. The IR receiver (TSOP1838) beam angle is +/-45º and hence data recognition occurs.

## V. CONCLUSION

A Li-Fi based automated smart trolley using RFID has been designed, simulated and implemented. At the beginning, the simulation of the research work was done on proteus to see how the device would function. The items were simulated with the help of switches which when activated, displays the corresponding item on the 20x4 LCD. The smart trolley system is capable of displaying items available on each aisle in the supermarket, and also helps in identifying items/products placed into the trolley, measure their weight, and display their price on the liquid crystal display, thereafter send the data via the infrared LED to the TSOP1838 receiver interfaced with the computer. The automated smart trolley is known to be an effective means of reducing long queues experienced during shopping.

## VI. FUTURE WORK

Despite the limitations of this design and observation made during testing proper, the following suggestions were made for further studies:

I. Automatic movement of the trolley could be considered in future work.

II. The smart trolley could interact with customers during a shopping trip. For example, passing on discount vouchers based on where they are in the supermarket.

III. The smart trolley could be enhanced to be used in libraries to borrow book, and book stores to purchase books.
IV. The concept behind this work could also be used in the department to implement a system that informs the head of department as to when each and every staff arrives and leaves the workplace.
V. Swapping the ATM card with this system to debit from the bank account at once.

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