Smart Shopping Cart

ELEG/CPEG 480- Capstone Design Project II

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Fall Semester, 2023

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The capstone project report is being submitted in partial fulfillment of the requirements for the degree of

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Fall Semester, 2023

Declaration

We certify that this project work titled "*Smart Shopping Cart*" is our own work. The work has not been presented elsewhere for assessment. The material that has been used from other sources has been properly acknowledged / referred.

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Abstract

Technology has transformed the manner in which we purchase goods, resulting in the rise of intelligent shopping trolleys. The objective of this ultimate assignment is to create a groundbreaking intelligent shopping trolley that simplifies the operations of retailers while enhancing the overall shopping experience for consumers. The suggested intelligent shopping trolley utilizes state-of-the-art technologies such as the Internet of Things (IoT), computer vision, and artificial intelligence (AI) to facilitate a smooth and customized shopping expedition. Intelligent shopping trolleys come equipped with an array of sensors and cameras that identify the articles positioned within. Computer vision algorithms help our system identify products, eliminating the need for manual scanning at checkout. Additionally, the cart is equipped with weight sensors to ensure accurate item detection and prevent item theft or accidental removal.

To improve customer’s shopping experience, smart shopping carts incorporate an AI-powered recommendation system. The shopping cart can deliver personalized product recommendations, promotions, and discounts suited to the shopper's interests by analyzing the products in the shopping cart as well as each person's purchasing history and preferences. This essentially spares customers time, but also encourages them to try new things. Additionally, smart shopping carts provide an intuitive user interface that provides real-time information such as product details, prices, and in-store locations. It also enables seamless payment options, allowing shoppers to complete transactions directly from their shopping cart, eliminating traditional checkout lines. From a retailer's perspective, smart shopping carts provide valuable insight into consumer and shopping behavior. The system generates data on popular products, frequently visited areas in the store, and customer demographics. This information allows retailers to optimize inventory management, marketing strategies and store layouts, ultimately improving profitability and customer satisfaction. In summary, this capstone project presents a state-of-the-art intelligent shopping cart that revolutionizes the shopping experience. Leveraging AI technologies, smart shopping carts enhance convenience, personalization, and efficiency for both consumers and retailers. With the ability to deliver accurate product recognition, personalized recommendations, and seamless payment options, smart shopping carts represent the future of retail by empowering shoppers and driving business success.

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Chapter 1 : INTRODUCTION

1.1 Introduction

This chapter introduces the background of the project, the need for the project and its purpose. It outlines the problem that the project is aiming to address and what the project is aiming to achieve. The project's goals and objectives are identified and explained. It also includes the SWOT analysis of the project.

1.2 Background

People from various walks of life may gather at the shopping mall to buy their daily necessities, including food items, clothing, toiletries, garden equipment, and other electrical goods. The number of small and major shopping malls has grown throughout the years in response to popular demand. As a result, infrastructure and shopping centers are improving to varying degrees. To give customers a high-quality shopping experience, several things need to be improved. Customers frequently have issues while buying [1].

With the development of technology, there has never been a greater desire to minimize human labor. The same applies to the world of purchasing. Shop owners used to manually arrange the things consumers picked and manually calculate bills in the past. However, the emergence of large supermarkets and shopping centers made manual product arrangement and delivery to clients, as well as manual bill calculating, look unrealistic and unattainable. The Barcode System is currently the shopping method utilized in malls. Although it has shortcomings, this system has superseded the earlier manual system. To begin with, a barcode system needs the product's barcode to be in the scanner's line of sight. It only has a scanning range of a few inches to a few feet. Only one product may be scanned at a time by a barcode scanner. Every product's kind is defined by its barcode, however they cannot do it individually. Barcodes are a read-only format that cannot be altered. The barcode system uses laser (optical) technology to operate. Barcodes need a significant amount of labor and human effort as well. Barcodes are readily damaged. In addition, the existing barcode method necessitates that customers wait in extended lines to have their purchases scanned and receipts issued. This procedure may be tedious and takes up a lot of the clients' time, which makes them even more impatient. Even with all of its drawbacks, the barcode technology is still in use. It is evident that a more intelligent and effective system is needed [2].

1.3 Problem Statement

Shopping in a mall is a common everyday activity in all cities. As most customers have discovered, they must spend a lot of time looking for items in the entire supermarket one by one and waiting in line for extended periods of time to pay their bills. The stress of standing in line has a detrimental impact on people's attitudes and might lead to miscommunication or dispute. Due to the barcode-based invoicing system, it is difficult to avoid standing in large lines especially over weekends or when there are discounts. Standing at a billing counter with a cart after collecting all of the things is an extremely stressful situation. Additionally, a traditional trolley needs to be physically pushed around the supermarket. The trolley gets heavier and more difficult to maneuver as more goods are added to it. Some of us find this scenario less convenient because the cart would be heavier to push with more goods added, this will be a difficulty for elderly and pregnant women. For smart purchasing, several technologies have recently been launched. Most of the solutions presented are related to payment systems only and do not address the problem of manually pushing the vehicle to deliver it to the cars.

1.4 Aims and Objectives of the Project

The project aims to solve the problem of traditional shopping carts by proposing a system that can be added to the cart to make it smart and avoid wasting time and effort while standing in long lines to pay shopping bills. It will also eliminate the need to push the heavy cart towards the parking lot to put the purchased items into the car. Thus, we suggest designing an Arduino-based system with three main parts: electronic, an Android application, and wireless communication between the system's controller and the Android application.

To clarify the project idea, here are the objectives of the project:

- Enable the user to interact with the cart system using a tablet through an Android Application.
- To use NFC technology for reading the item's information and adding it to the purchase list on the Android application.
- To enable the customer to search the department of any item in the supermarket to find it.
- To design the cart system with the ability to move automatically by itself without the need to push it physically to be delivered to the car parking lot.
- To enable the cashier to know whether the customer has paid or not.

- To use rechargeable batteries for powering the system and Photovoltaics for charging both the batteries and the tablet.
- To use effective wireless communication between the cart's system and the tablet's Android application.
- To enable the customer to pay the purchase bill easily by generating a bill at the cashier system through the application.

1.5 Significance, Scope and Definitions

The designed system can be included in the traditional shopping cart to make it more intelligent and prevent people from spending time and effort waiting in lengthy lines to pay for purchases. Additionally, it will eliminate the need to push the heavy cart towards the parking lot to put the purchased items into the car. An Android application will be used to enable the user to interact with the cart's system by adding, removing, and searching for items. It will also be used to show the user the purchase list and enable him to generate a bill once he wants to check out. The trolley will work in 2 modes: the manual mode will be achieved by pushing the trolley by the customer while shopping, and the automatic mode will be achieved by moving the cart by itself into a certain path with the help of some sensors for detecting the obstacles in front of it and on the right path to the parking lot where the car is parked.

1.6 SWOT Analysis

The strengths, weakness, opportunities and threats of the project are listed in Table 1.1.

Table 1.1: SWOT Analysis

Strengths	**Weakness**	**Opportunities**	**Threats**
• Cost effective. • Low power consumption. • Easy to use. • Reduce shopping time. • Using NFC would make the process of scanning items more beneficial. • No need for physical effort for pushing the full cart to deliver it to the cars parking. • Using an Android application to enable the user to interact with the cart's system. • Lithium ion batteries provides high energy density and low maintenance. • Increase efficiency and convenience for shoppers.	• PV panel efficiency may be affected by weather conditions. • The project will be designed for a limited number of items.	• It can be used in supermarkets and malls. • Increase sales and profits. • It can be useful for elders and pregnant women. • The system can be extended by increasing the number of items.	• Lithium-ion cells cause little harm when disposed. • Mechanical issues. • PV panels may be damaged due to human misuse.

Chapter 2 : LITERATURE REVIEW

2.1 Introduction

In this chapter, we survey the most related work to our system "Smart Shopping Cart”. Each project described in these papers is summarized based on its main idea, working principle, and technology used.

2.2 Related Work

2.2.1 Smart Shopping Cart with Automatic Billing System using RFID & Arduino

This project introduces a smart shopping cart that uses RFID technology for scanning the items that the user wants to purchase and adding them to the bill. Every product in this system has an RFID tag, and each cart is equipped with an RFID reader. Once an item is scanned, its price will be automatically added to the bill. In this project, the item name and price are shown on the LCD Display. The system implementation is shown in Figure 2.1. The Arduino Nano Board, which houses the project code, serves as the primary controller of this project. All operations, including reading information from RFID Cards and computing pricing, are handled by the Arduino. When an RFID is scanned, the buzzer activates. Based on the addition or removal of objects, the red and green LEDs turn on and off. The objects can be removed from the billing list by holding down the reset button while scanning the RFID [3].

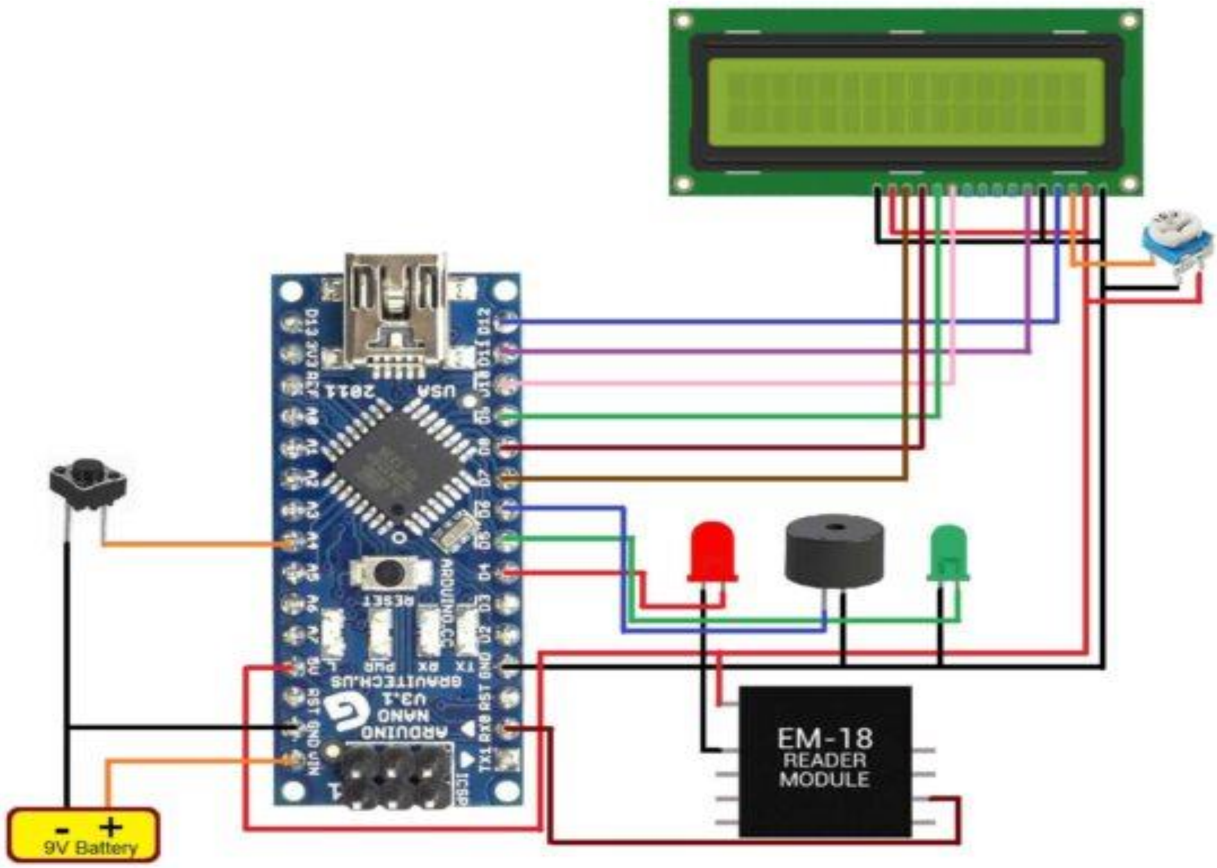

Figure 2.1: System implementation [3].

2.2.2 Smart Shopping Cart with Automatic Billing System through RFID and ZigBee

This is a centralized and automated billing system that uses ZigBee and RFID technology. Each item at the supermarket is armed with an RFID tag to indicate its category. As shown in **Error! Reference source not found.**, each shopping cart has a Product Identification Device (PID), an LCD, an RFID reader, an EEPROM, and a ZigBee module. Product information for purchases will be read using an RFID reader on the shopping cart, while product data are saved in an EEPROM linked to it and sent to the central billing system using a ZigBee module. The central billing system obtains the cart's data and EEPROM information, accesses the product database, and determines the total cost of the cart's purchases [4].

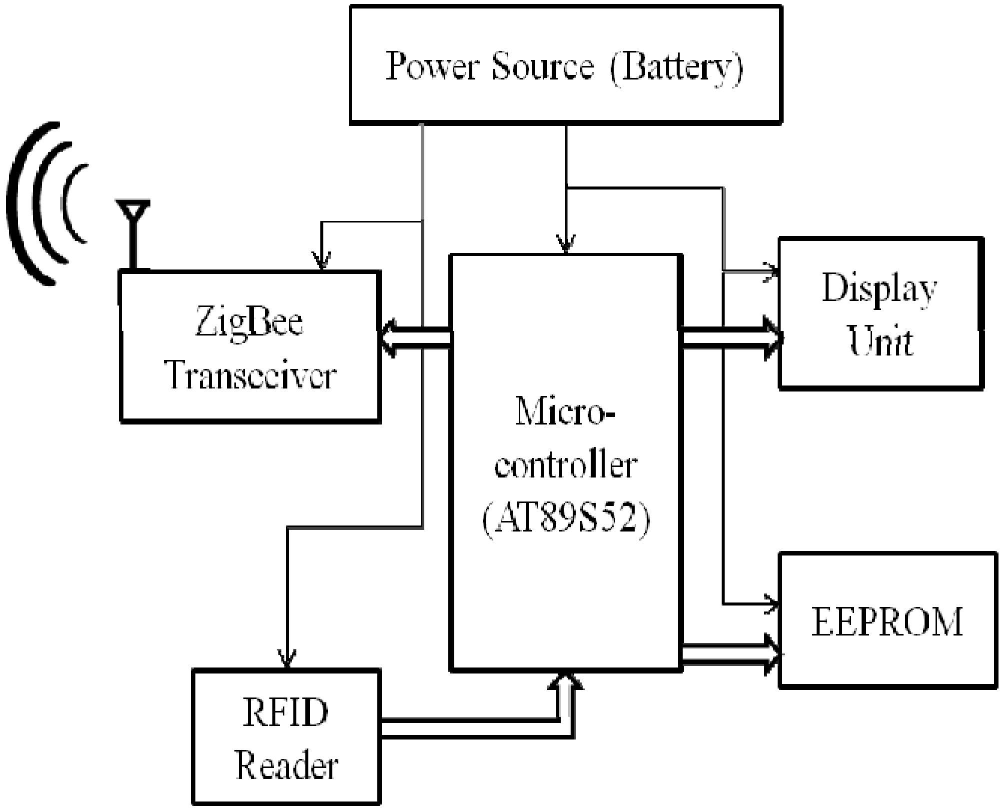

Figure 2.2: Hardware Implementation of Shopping Cart [4].

2.2.3 Smart Shopping Cart Using RFID Technology

The system presented in [5] includes a shopping cart that is integrated with an RFID reader module, and the goods are RFID-tagged. When a consumer enters the supermarket, he/she scans the QR code to log in to the designated trolley and begin shopping. Each shopping trolley is tagged with a QR code. An item is instantly scanned by the RFID reader and added to the shopping cart when the consumer places it in the trolley. When registered users enter the store, they can utilize the mobile application to log in to the associated trolley that was taken by them. The RFID reader instantly reads the item when it is placed in the trolley and adds it to the shopping cart. Billing is therefore possible right from the purchasing basket. There is no need for personnel for billing since after the consumer has done buying, a bill is created in the cart, and the money is immediately withdrawn from the shopping wallet that was issued to the user. Finally, OLED screen is used to show the total bill.

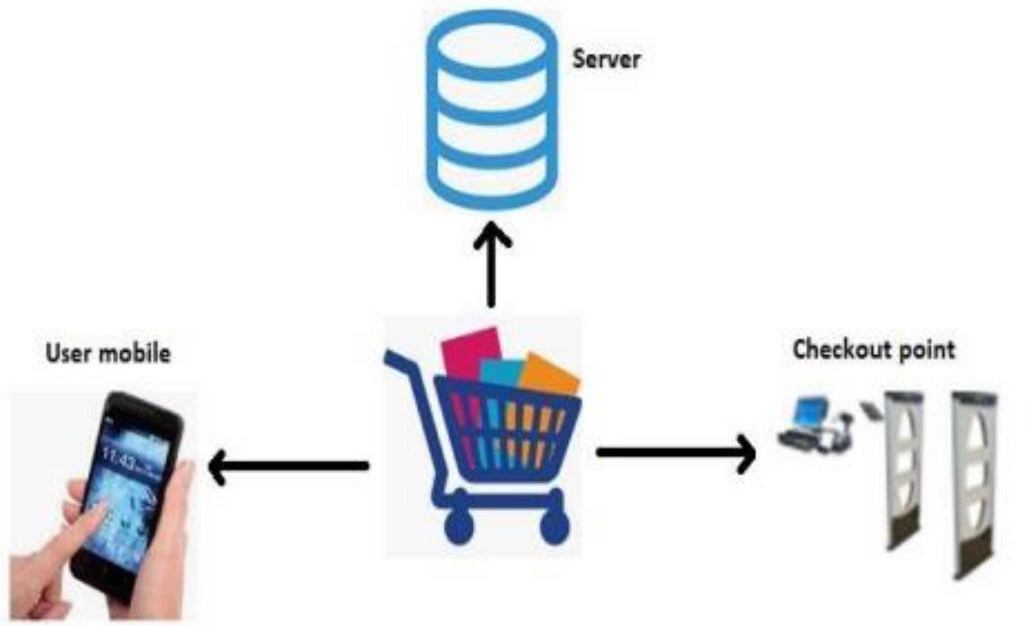

Figure 2.3: Smart cart design [5].

2.2.4 Development of an Improve Automated Shopping Trolley Payment System Using A Barcode Scanner and Weight Sensor

This study created a device that is mounted on the shopping cart and allows customers to finish their billing transactions without standing in long lines. To do this, every item in the market should have barcodes printed on it, and every shopping cart should contain an LCD screen, a weight sensor, and a barcode scanner. The system circuit diagram is shown in **Error! Reference source not found.**. When a consumer scans an item, the code is instantly recognized, and the weight, price, and name of the items are shown on the LCD. As a result, the cost is added to the final bill. When a consumer wants to take an item out of the trolley, they just push a button, rescan the item, and the weight and amount of that item are subtracted from the total [6].

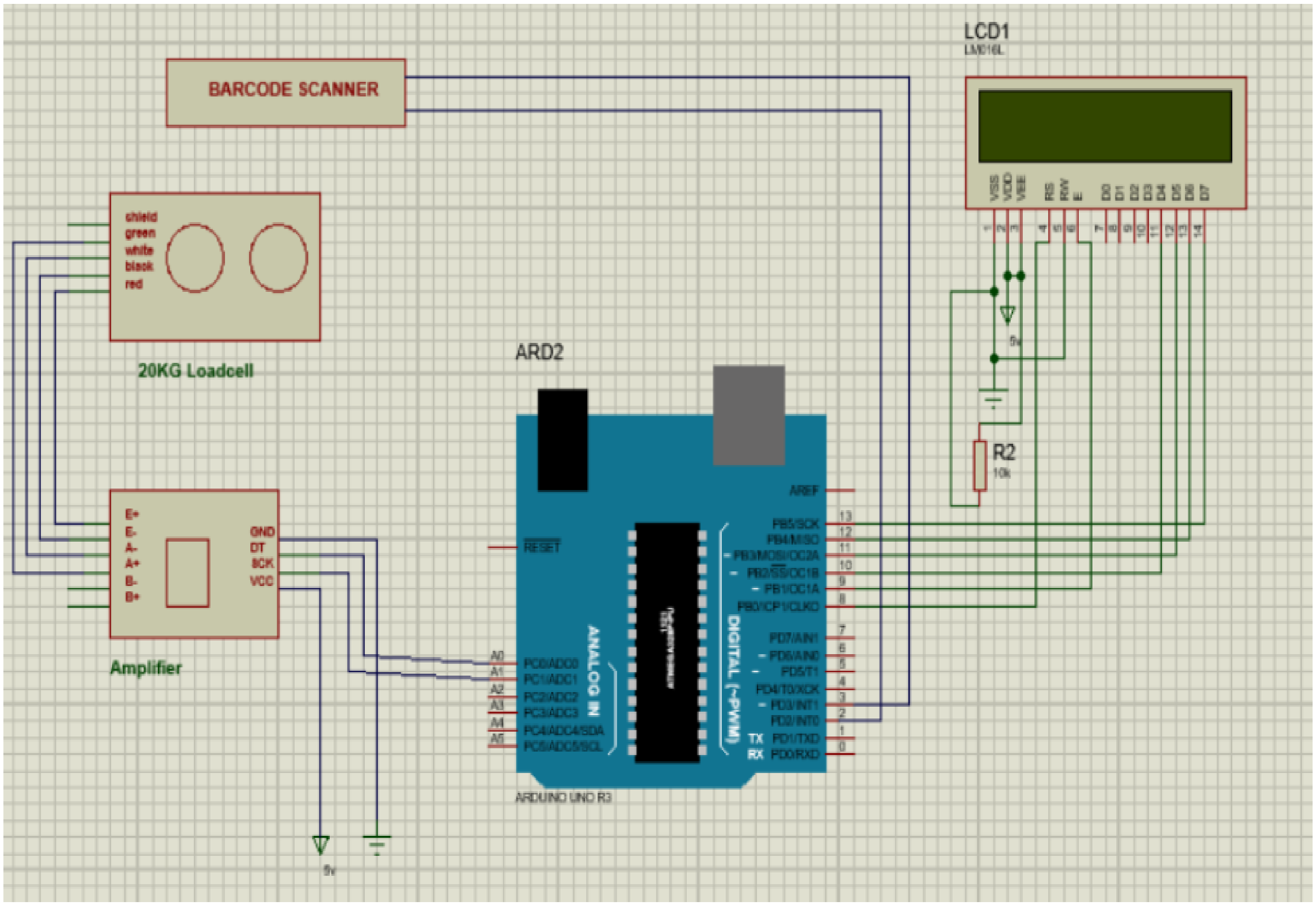

Figure 2.4: Circuit diagram of system implementation [6].

2.2.5 Smart Shopping Trolley Using Raspberry PI

The authors in [7], have built a system that consists of a loadcell, camera, and LCD display that are linked to a Raspberry Pi. To add a product, remove a product, and create a bill, buttons are used. The database of some items in the market is saved on the Raspberry Pi. The technique employed here is crucial in transforming the camera into a scanner to read the barcode. The product must be scanned by the consumer before being added to the cart. To issue the bill, the chosen product weights and the database weights must coincide. The buzzer will sound a warning when there is a weight discrepancy between the product weight placed in the trolley and the weight of that product in the database. Additionally, it alerts users when theft occurs. After making a purchase, a button must be hit to produce a bill that will be delivered to the customer's mailbox and the billing counter for the final payment.

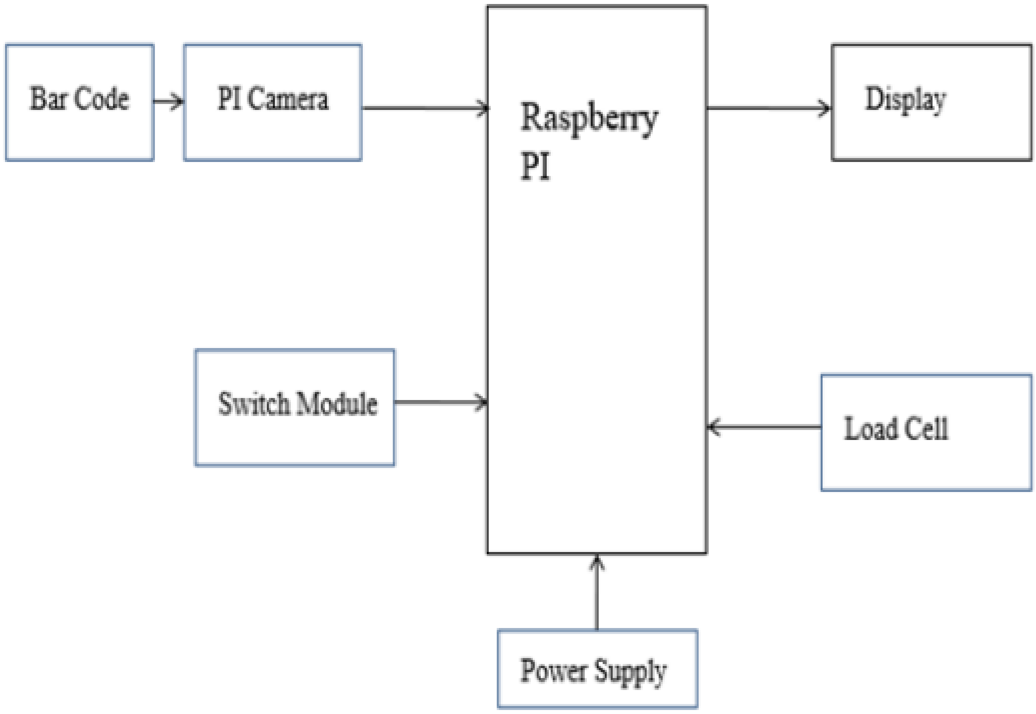

Figure 2.5: Block Diagram of Smart Shopping Trolley [7].

2.2.6 Secure Smart Shopping System Using Android Application

In this system, users must download and install the program on the Android phone. They then scan the QR code for the product and enters the quantity. Scanned items are then placed on the shopping cart. Users collect the items in this way and add them to their shopping carts. Products can be added to or removed from the cart by the user. The bill is created when the items have been purchased. Through online banking service, this bill could be paid through the client's mobile device [8].

2.2.7 Follow Me Smart Shopping Trolley

In the work presented in [9], a smart trolley will begin to follow the user no matter which direction they are travelling in and will also identify any obstructions in its route when a client approaches it and turns it on. This system uses an Arduino Uno, an ultrasonic sensor, and an infrared sensor. To identify persons, the model employs an ultrasonic sensor. A left-side IR sensor and a right-side IR sensor are used by the model to turn the trolley. An ultrasonic sensor in the trolley recognizes a person in front of it when it is turned on. In the prototype, when the user moves, the sensor starts to follow them and keeps a 30 cm distance between them and the trolley.

A left-side IR sensor also allows the trolley to turn to the left when a person turns to the left. Similar to how a human moves to the right, the trolley rotates to the right when an IR sensor on the right side is activated. If the passenger stops moving, the trolley stops immediately. When the person in front of the prototype trolley advances past the range of 30 cm to 100 cm, the trolley also stops.

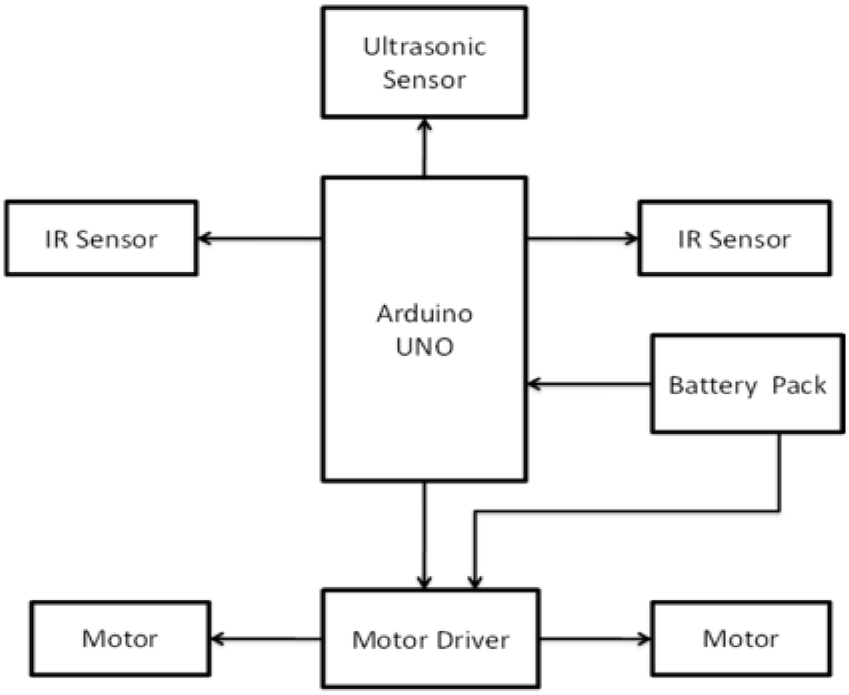

Figure 2.6: Follow Me Smart Shopping Trolley block diagram [9].

2.2.8 Design and Implementation of a Smart Shopping Trolley Using RFID Technology

The authors in [10] designed this smart trolley to modernize and facilitate the use of market services. The automated control of the trolley's movement by the remote lessens the strain on the customer when they are pushing the trolley. Additionally, it assists in conserving money by preventing the purchase of unnecessary items thanks to the trolley's Liquid Crystal Display, which updates the purchase limit. The customer enters the amount they have via the keypad in this task, and the amount is shown on the liquid crystal screen. The price and RFID information of the used merchandise are then verified. This information is transmitted from the product's RFID by radio waves to the RFID reader. It has an antenna bar for data transmission and reception. The scanner for materials provided to Arduino in memory compiles the total cost. The client's actions while shopping determine how the cart goes, and the buttons allow the cart to move left, right, forward, backward, or even stop. An alert will sound to warn the consumer that he or she has surpassed the purchase limit if the customer purchases more goods than the quantity noted on the keypad.

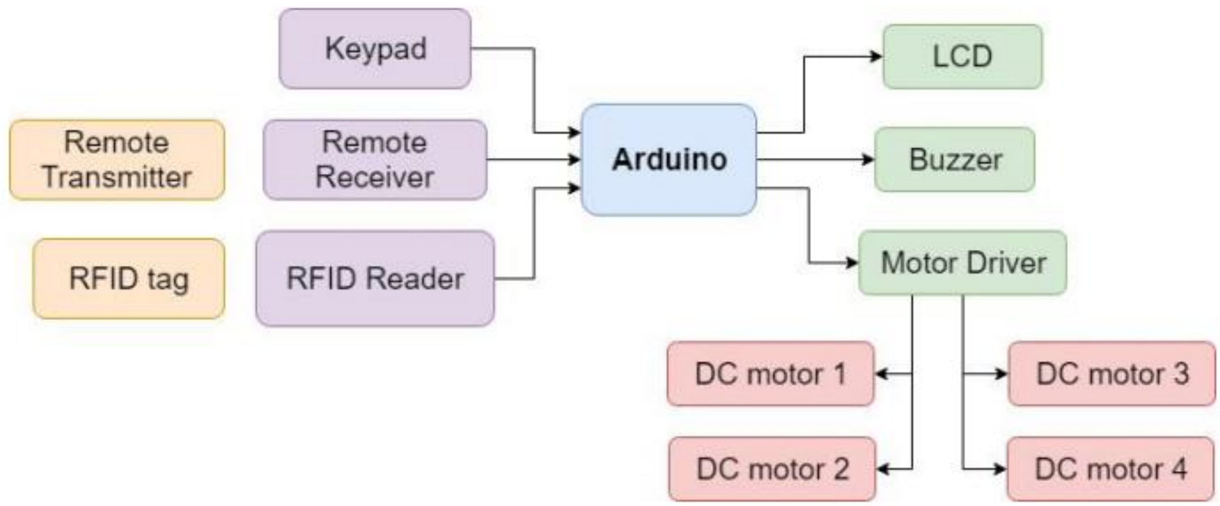

Figure 2.7: System block diagram [10].

2.2.9 Android Application for Smart Shopping

The authors in [11] developed an Android Application for Smart Shopping. They have created a database for the smart phone and Arduino. The system block diagram is shown in **Error! Reference source not found.**. The items are bought and placed in the cart; when the barcode on the product is scanned, the product is detected by an ultrasonic sensor. In this manner, products are added to the list of purchases that are Bluetooth-send to a mobile application. In the app, update the list. The buzzer will sound for 5 seconds if the ultrasonic sensor does not detect the product. This indicates that the product was not added to the cart. A buzzer turns on if the consumer removes the item from the Android application but forgets to remove it from the shopping cart. If the item is within range of these ultrasonic sensors for 5 seconds after being removed from the app, the buzzer will turn off. This buzzer is coupled to ultrasonic sensors installed within the cart.

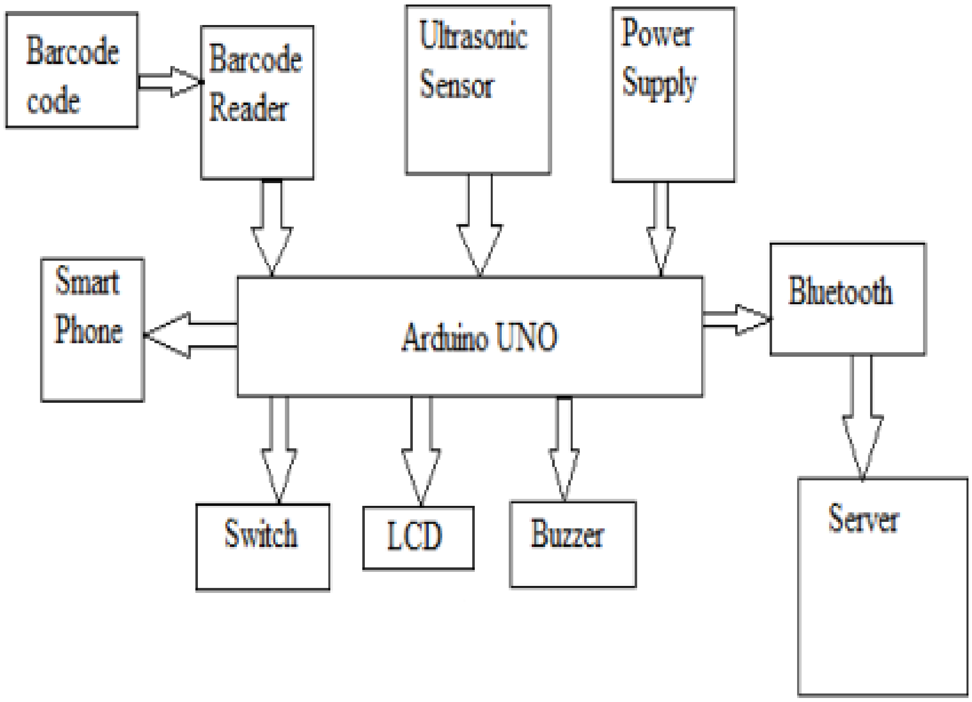

Figure 2.8: Block diagram of Android Application for Smart Shopping system [11].

2.2.10 Smart Trolley Using Bluetooth Module

The Authors in [12] created a smart trolley using a Bluetooth module which is shown in Figure 2.9. They have replaced barcodes with RFID tags. The available products are completely RFID-tagged. The passive RFID tag features a built-in power source. When a shopper buys a product and places it in the smart trolley, the product's details, including price and name, are shown on an LCD. Following trolley complete billing, the data is sent to the main billing department computer via a Bluetooth module.

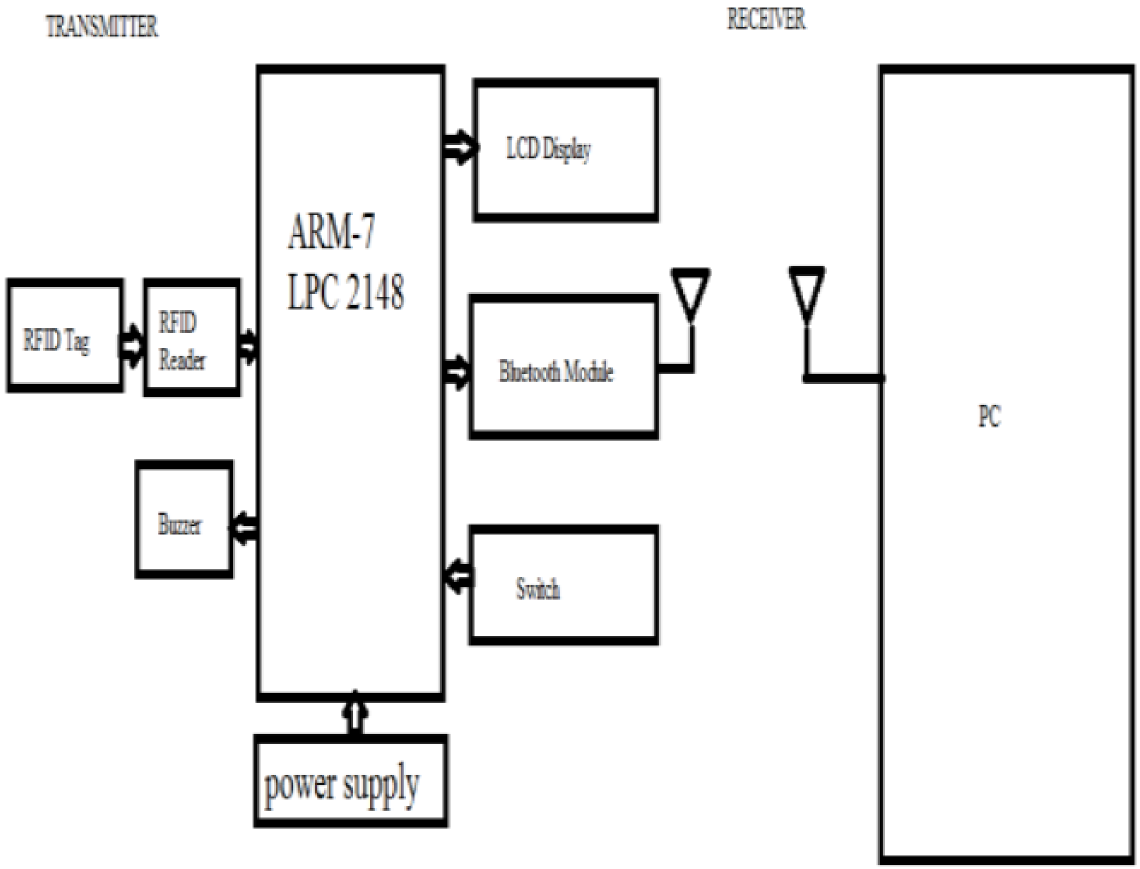

Figure 2.9: Prototype of the designed system [12].

2.3 Summary and Implications

After searching, reading, and surveying many papers, we made a comparison table to show the main key features of each project and the drawbacks of it as shown in Table 2.1.

Table 2.1: Comparison table of surveyed projects.

Title	Key features	Drawbacks
Smart Shopping Cart with Automatic Billing System using RFID & Arduino [3]	• It uses an LCD for displaying the scanned item's name and price. • It enables the user to remove any item from the billing list.	• The LCD can display a limited number of characters • The system didn't have any connection with a central billing system. • It can't be used to solve the problem of pushing the cart physically. • It didn't use any applications to enable the user to interact with the cart and control it easily.
Smart Shopping Cart with Automatic Billing System through RFID and ZigBee [4]	• It uses RFID reader to scan the items. • Item's data are sent to the central billing system using a ZigBee module.	• The LCD can display a limited number of characters. • It can be used as a paying system only. • It can't be used to solve the problem of pushing the cart physically
Smart Shopping Cart Using RFID Technology [5]	• It uses a mobile application to log in to the trolley by scanning QR code. • It uses RFID reader to scan items. • The money is withdrawn from the user's shopping wallet.	• It can't be used to solve the problem of pushing the cart physically. • The OLED screen is only used for showing the total bill only. • There are no much details about the mobile application and how the user can remove an item from the bill.
Development of an Improve Automated Shopping Trolley Payment System Using A Barcode Scanner and Weight Sensor [6]	• Small number of components • Not complicated. • Once the item's barcode is scanned, its price, name and weight will appear on the LCD.	• It can't be used to solve the problem of pushing the cart physically. • The LCD can display a limited number of characters. • The system can be used as a payment system only. • The need of line of sight to scan the item's barcode.
Smart Shopping Trolley Using Raspberry PI [7]	• The system uses a camera to scan the item barcode. • The system alerts the customer when there is a weight discrepancy between the added product's weight and the weight in the database. • It alerts users when theft occurs. • It enables the user to set the budget.	• It can't be used to solve the problem of pushing the cart physically. • User can't get the bill in case he doesn't have an internet connection on his mobile. • The LCD is small and can display a limited number of characters. • The system wouldn't be cost effective due to using a camera and Raspberry pi. • The Camera lens should be clean.
Secure Smart Shopping System Using Android Application [8]	• I uses a mobile application to scan the item's QR code. • The system will show the user some suggested products. • The bill will be delivered to the client's mobile device.	• It can't be used to solve the problem of pushing the cart physically. • The customer should download the application on his mobile previously; he can't use the system in case he doesn't have an internet connection. • The customer should enter the quantity of each item manually.

Follow Me Smart Shopping Trolley [9]	• It can be used to move by itself. • It uses Ultrasonic sensor to identify persons in front of it and IR sensors to allow the trolley to turn to the left and right to follow the user's steps.	• It has no features to scan added/removed items to/from the trolley and generate a bill.
Design and Implementation of a Smart Shopping Trolley Using RFID Technology [10]	• The customer can control the trolley remotely. • It uses an LCD to show the budget. • It warns the consumer when the purchase limit is succeeded.	• It doesn't have features of detecting obstacles • It hasn't the ability to move in a certain path automatically. • The LCD is small and can display a limited number of characters. • Using a remote control to move the trolley may lead to many faults.
Android Application for Smart Shopping [11]	• Item is added to the list when it's detected by an ultrasonic sensor. • The system is connected to the smartphone via Bluetooth. • It warns the user if the ultrasonic sensor does not detect the scanned product or the consumer removes the item from the Android application but forgets to remove it from the shopping cart.	• The user should use his own mobile and connect it with the system. • The need of line of sight to scan the item's barcode. • It can't be used to solve the problem of pushing the cart physically.
Smart Trolley Using Bluetooth Module [12]	• It uses RFID reader to scan the items. • The bill details are sent to the main billing department computer via a Bluetooth module.	• It can't be used to solve the problem of pushing the cart physically. • The LCD is small and can display a limited number of characters.

Chapter 3 : METHODOLOGY, DESIGN AND ANALYSIS

3.1 Introduction

This chapter introduces the project methodology, the research design, the hardware and software that are used for implementing the system, the system's cost, the analysis of project working, and the ethical considerations and limitations.

3.2 Methodology

We have choosed the waterfall methodology in this project. Project Waterfall methodology (as can be shown in Figure 3.1) is a structured approach to software development that follows a sequential process of planning, analysis, design, implementation, testing, and maintenance. The main idea is to plan out the entire project before beginning the actual development process. This helps to ensure that all necessary tasks are completed in a timely manner and that the project is completed as efficiently as possible [13].

- The planning phase of the project is the most important step as it helps to define the scope of the project, the goals and objectives, and the timeline. During this phase, a project manager or team leader will create a list of tasks and activities that need to be completed and assign a timeline for each task. This will ensure that the project stays on track and that the project goals are met.
- The analysis phase involves analyzing the requirements for the project and determining the most effective way to meet the project goals. This includes researching existing solutions and technologies, identifying the necessary resources, and assessing the cost of the project. This phase also includes risk assessment and identifying any potential risks that could affect the project.
- The design phase involves developing a plan for how the project will be built, including the architecture and design of the software. This includes the selection of the appropriate technologies, the design of the user interface, and the integration of the software with other existing systems.
- The implementation phase involves writing the code and testing the software. This includes writing the code, debugging it, and conducting unit tests to ensure that the software meets the requirements. Once the software is tested and verified, it can be released to the public.

- Finally, the maintenance phase involves ensuring that the software is up to date and running smoothly. This includes bug fixes, security updates, and other necessary changes to ensure that the software continues to meet the requirements. The maintenance phase is also important to ensure that the software remains compatible with other existing systems.

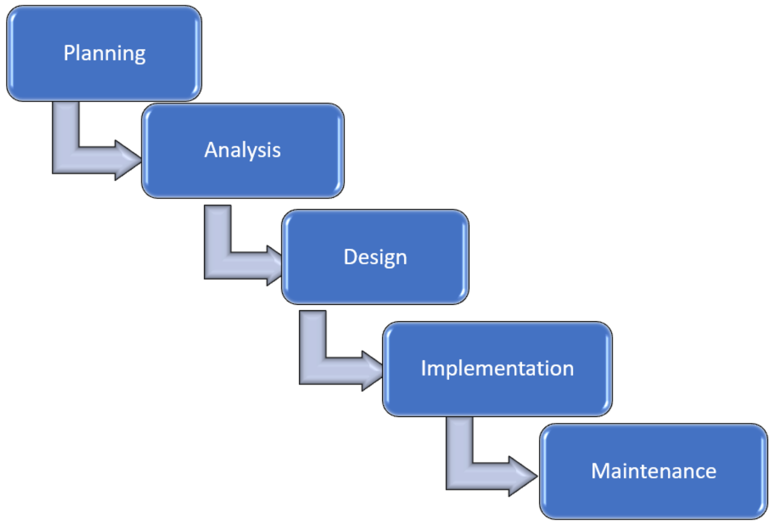

Figure 3.1: Waterfall methodology [13].

3.3 Research Design

The system block diagram is shown in Figure 3.2, it shows the components that are attached to the cart. The tablet is used as an interface between the user and the cart's system using an Android Application that has been developed and downloaded on the tablet. The Bluetooth module is used to connect the cart's system with the tablet. The system is based on NFC technology; where NFC reader is used for scanning the item's NFC tag attached to it to read its information, send it to the system controller (Arduino). Then, the scanned item details will be added to the purchase list on the Android application. The two DC motors are used to move the cart when the user activates the automatic mode to deliver the cart to the car by attaching 2 extra wheels to these motors. The motor driver is used to amplify the Arduino's output power.

In order to enable the cart to move independently, a servo motor is used as a jack (up/down motor) to move the motors and the wheels in a way that raises the rear wheels of the cart. A LED strip is used to enable the cashier to know if the customer had paid his bill or not; the LED will be lighted in different colors; red color as an indication that he didn't completed his purchase, green

LED as an indication that he completed his purchase and paid the bill, blue color as an indication that the cart is available to be used for shopping. The ultrasonic sensor is used for detecting objects and obstacles when the cart is moving automatically to avoid collisions, while the buzzer is used to start a sound alert when an obstacle is detected. The line following sensors are used to enable the cart to move in a certain path towards the car in the parking according to the parking lot number that can be determined by the customer through the tablet.

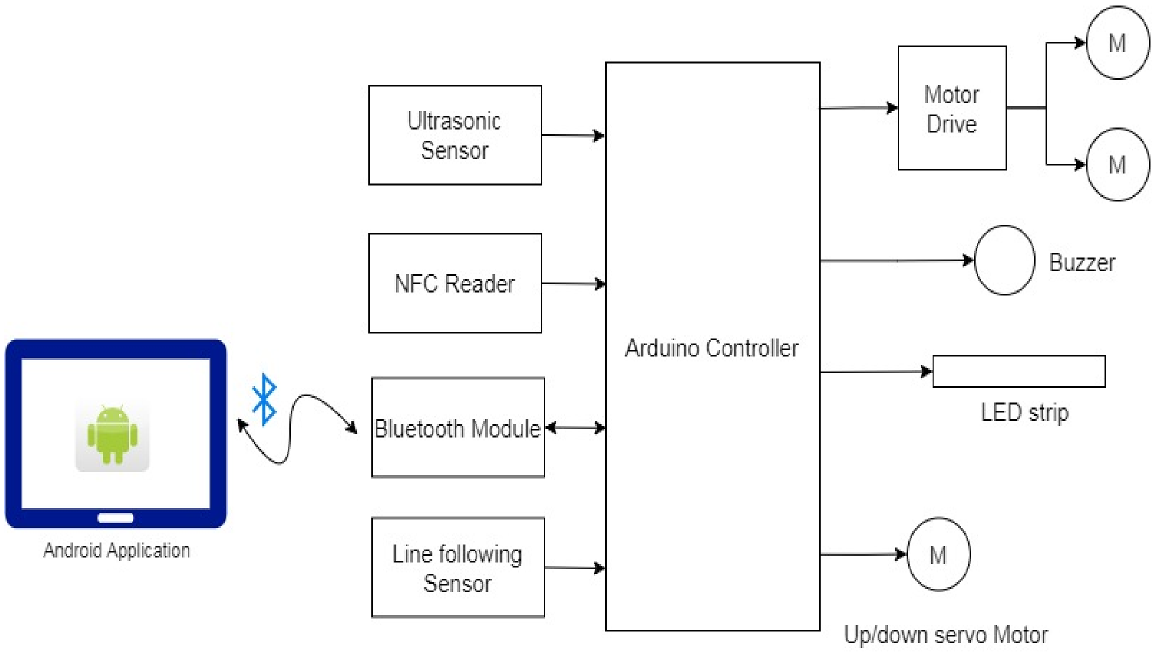

Figure 3.2: system block diagram.

The system is powered by 3 rechargeable batteries (3.7v/each) that will be charged by the Photovoltaics are attached to the right and left sides of the cart. A boost converter is used to step up the voltage generated by the Photovoltaic panels to a higher voltage to charge the 3 batteries. The protection board is used to protect the batteries while charging and discharging. The 3s charger is used for charging the system via USB cable. Finally, two voltage regulators are used to step down the voltage to 5V that is needed to power the system and the servo motor.

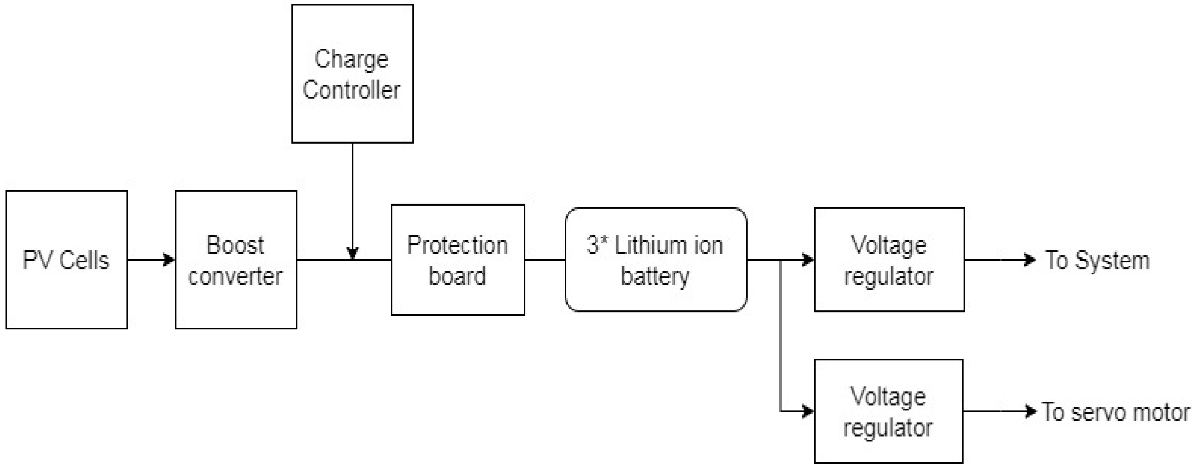

Figure 3.3: power supply diagram.

According to the Android application graphical user interface (GUI), it should include a main GUI where the added item's information such as its name, quantity, unit price, the total amount of each item, the bill's total amount , and the battery charge will be shown. Using the GUI, the customer will be able to add and remove an item, search for an item, and to check out. The proposed GUI is shown in Figure 3.4. The developed GUI is discussed in the next chapter.

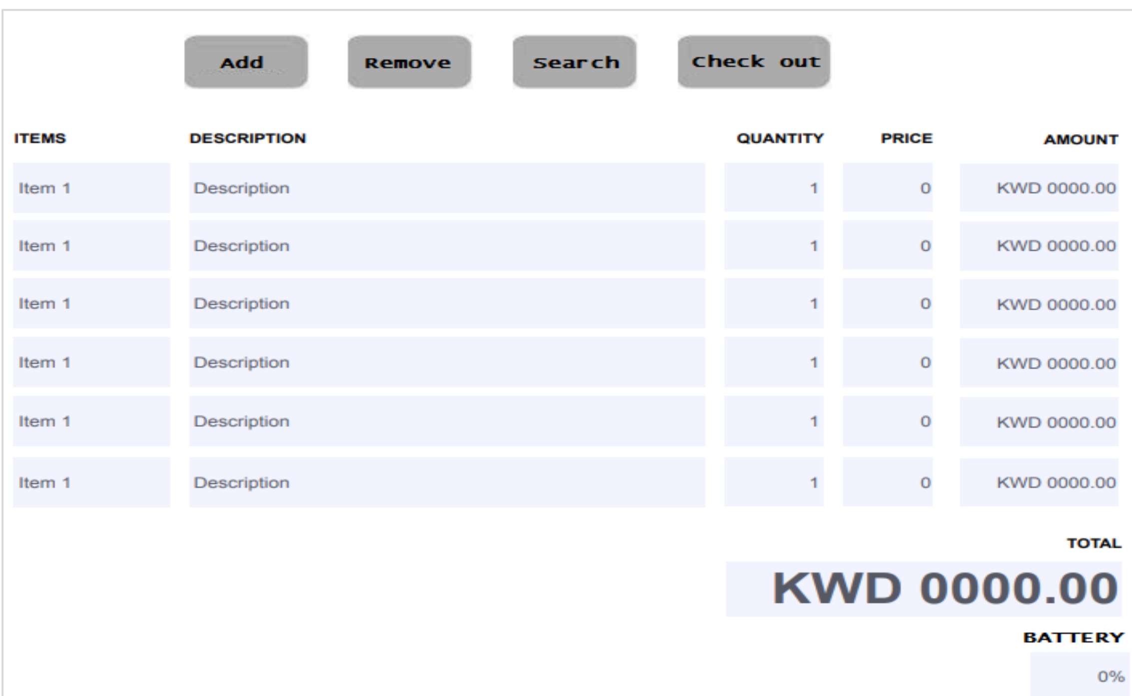

Figure 3.4: Main GUI.

When the customer presses “search button”, the second GUI will appear to enable him to enter the item name and a virtual map to guide him where to find the item.

Figure 3.5: Search GUI.

Finally, when he presses “check out” button, a flash message will appear to ask the customer if he wants to check out. If he pressed “YES”, then his purchase list will be sent to the cashier to pay the bill. When he paid and the cashier released his cart, a message will appear to ask the user if he wants to deliver his cart to the car in the parking. In case he wants to deliver the cart to his car, he should fill his car’s parking lot number.

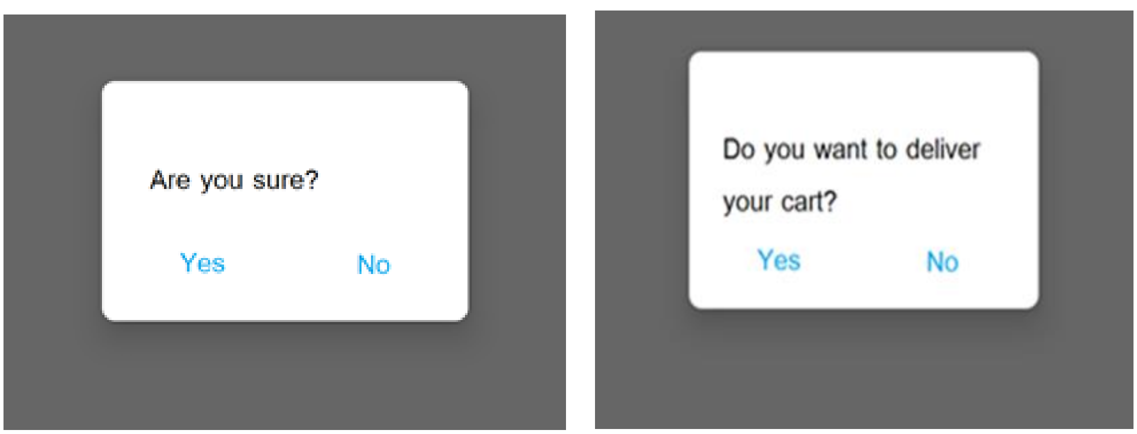

Figure 3.6: Check out- GUI.

3.3.1 Design Alternatives

For the system’s controller, we suggested two types of Arduinos: Arduino Nano and Arduino Uno. Both boards have the same speed, similar processing power, and the same microcontroller. We will go with the Arduino Nano due to its smaller size and lower price.

For the wireless connection, we suggested using Bluetooth or WiFi. We will go with the Bluetooth connection because it's simpler to use, has low power consumption, and is cheaper. Additionally, the project's application doesn't need a long range of transmission.

To control the cart's movements, we suggested using a joystick or using motorized wheels instead to pull the rare wheels of the cart up and down. We go with the second solution to make the cart move independently without human interaction.

3.4 Software and Hardware

3.4.1 Arduino Nano

The Arduino is an electrical platform that aims to make it simple to get started with electronics while yet allowing users to construct more difficult projects in the future. It was made with simplicity and use in mind. The Arduino Nano is based on the Atmel (Microchip Technology) ATmega328 8-bit microcontroller. It is functionally identical to the Arduino Uno but comes in a smaller package. The Arduino Nano has 14 digital pins, 8 analog pins, 2 reset pins, and 6 power pins. Due to its modest size and breadboard friendliness, this device is the ideal choice for the majority of applications where the size of the electrical components is a key factor. The Arduino IDE, which can be downloaded from the official Arduino website, is used to program it. Atmega328 flash memory has a 32KB capacity which is used to store the code. It has a 1KB EEPROM memory and a 2KB SRAM memory [14].

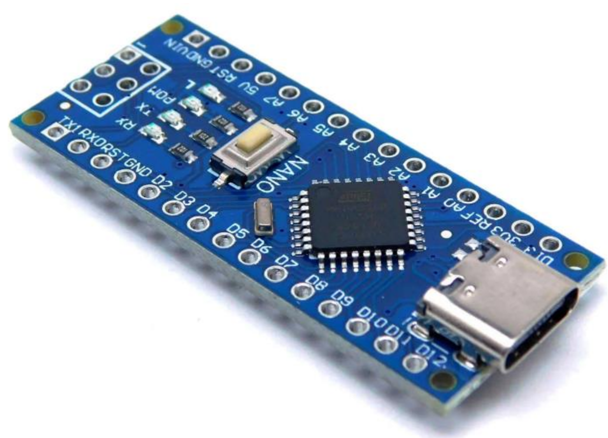

Figure 3.7: Arduino Nano board.

3.4.2 NFC Reader (PN532)

A popular wireless technique called near field communication (NFC) permits data transmission between two adjacent devices. NFC is a set of protocols that enables smart phones and other similar devices to communicate wirelessly by touching or coming very close to one another typically within a few millimeters. Based on the 80C51 microcontroller core, the PN532 is a highly integrated transceiver module enabling contactless communication at 13.56 MHz. It is commonly used in place of QR codes for other short-range applications like mobile payments since it is speedier and more secure. Practically speaking, the technique is rather straightforward; data from various NFC tags is read using electronic reader devices. Despite this, NFC tags are incredibly flexible and frequently useful when you need to convey brief amounts of data fast [15].

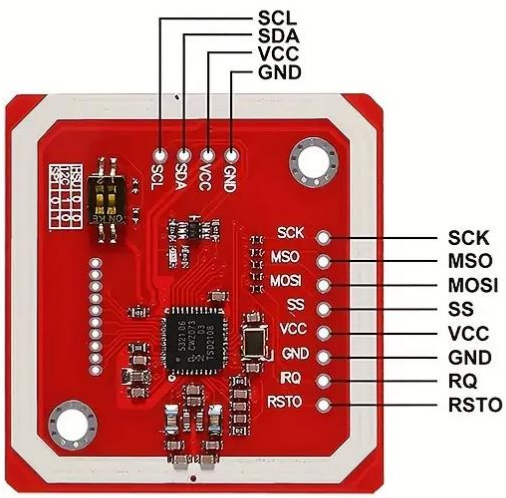

Figure 3.8: PN523 NFC reader pinout.

3.4.3 Bluetooth Module (HC-06)

A Bluetooth BLE module is a piece of technology that sets a mechanism for data transmission between devices and serves as an interface for wireless Bluetooth Low energy connections between any two devices. The average mediated data transmission range of a Bluetooth low energy module is typically tens of meters, and data is transmitted in designated frequency bands. Bluetooth modules are useful for many different things and have a wide range of uses. As they can be linked to microcontrollers to turn on or off the light, they may be utilized as light switch controllers [16]. The HC-06 Bluetooth module was created to enable wireless data transfer over short distances between two microcontrollers or systems. The module can only function as a slave device and utilizes the Bluetooth 2.0 communication protocol. In comparison to other techniques, this one is more versatile and less expensive, and it can even send files at a pace of up to 2.1Mb/s [17].

Figure 3.9: HC-06.

3.4.4 Ultrasonic Sensor (US-016)

Ultrasonic sensors use ultrasonic waves for distance measurement. They emit ultrasonic waves and then measure the time it takes for the waves to bounce back after hitting an object. The distance to the object is calculated based on the speed of sound in the air. The US-016 ultrasonic starting module supports an analog output voltage, is stable and dependable, and has non-measurement capabilities up to 2 cm ~ 3 m. This makes it suitable for use in a wide range of projects, from simple obstacle avoidance systems to more complex systems. Its supply voltage is 5 V, and its working current is 3.8 mA [18].

When the range of the floating pin is three meters, this module may vary based on the situation it is applied to (maximum measurement range for each one meter and three meters).The analog output voltage produced by the US-016 measuring distance converter is proportionate to the measured distance. The sensor operates by emitting a high frequency sound wave and then measuring the time it takes for the wave to bounce back from the target object. This time is then converted into distance using the speed of sound (343m/sec). The US-016 has a built-in microcontroller that controls the emission and reception of the ultrasonic waves, making it a self-contained and easy to use device [19].

Figure 3.10: US-016 Ultrasonic sensor.

3.4.5 Line Tracking Sensor

The TCRT5000 Infrared Reflective IR Photoelectric sensor which is shown in Figure 3.11 will be used in this project as the line tracking sensor. This (IR) reflection-based line detection sensor module is incredibly simple to operate. For mobile robot line detection, the sensor has been installed at the module's base. It has an internal potentiometer that may be used to change the sensitivity. Since the output is a digital signal, any microcontroller, including Arduino and Raspberry Pi, may be easily interfaced with it. Because it relies on light reflection, the detection varies depending on the surface. This sensor is compatible with the Arduino since its operating voltage is 3.3V or 5VDC. It is compact which makes it easy to assembly [20].

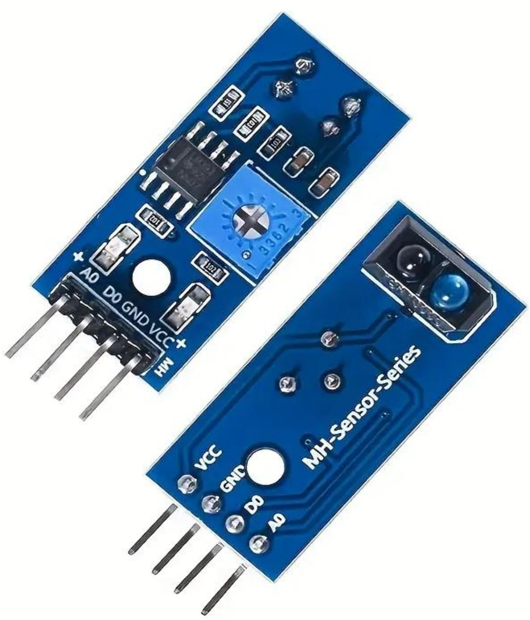

Figure 3.11: IR line track sensor module.

3.4.6 Digital Servo Motor (RDS3115MG)

The RDS3115MG digital servo motor is a high-performance motor that is designed for the most demanding applications. It is a brushless DC motor with a high-torque, low-noise design that can handle the toughest loads. The motor has a voltage range of 4.8V to 6.0V and a maximum continuous torque of 11kg-cm. It is designed to be used in helicopters, cars, boats, and robots, and has a response speed of 0.12 seconds/60 degrees at 4.8V. The motor also features a durable steel gear train with aluminum and plastic gears for maximum efficiency and reliability. It also has a high-resolution, digital coreless motor that delivers accurate and smooth control [21].

Figure 3.12: RDS3115 Servo motor.

3.4.7 DC Gear Motor with Wheel

DC gear motors are an incredibly useful and versatile motor solution for a variety of applications. They offer a great combination of power, speed, and torque for a wide range of applications. DC gear motors come in a variety of sizes and configurations, so you can find one that fits your exact needs. The gearbox inside the motor helps to reduce the speed of the motor, while increasing its torque output, making them ideal for applications that require power and precision. They also offer a range of features such as reverse rotation, variable speed, and regenerative braking, providing a range of options for the application. DC gear motors are also easy to install and maintain and can be used in a variety of environments, making them a great choice for a wide range of applications [22].

Figure 3.13: DC Gear Motor with Wheel.

3.4.8 Motor Drive Module (L293D)

The motor driver module shown in Figure 3.14 has a powerful 4-channel driver as its primary IC the L293D. With heat protection, this board has a 0.6 A (1.2 A peak) control capacity for four channels. 4.5V to 25V DC can be supplied (external power source is conceivable). Pull-down resistors are used to turn the motors off at startup. The L293D is a dual-channel H-Bridge motor driver that can power either one stepper motor or two DC motors. Due to its ability to operate up to two motors independently, it is perfect for constructing a two-wheeled robotic platform [23].

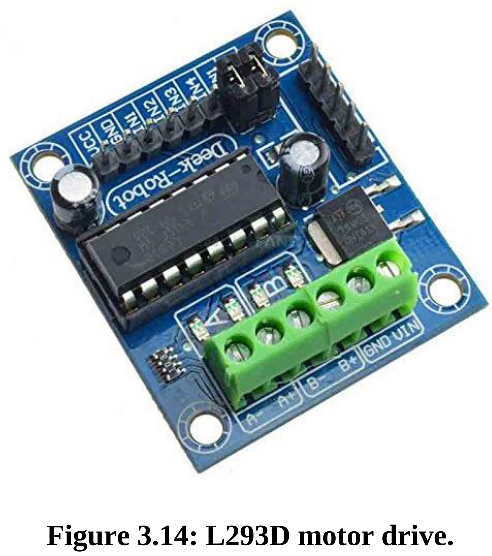

Figure 3.14: L293D motor drive.

3.4.9 Photovoltaics

Photovoltaics (PV) solar cells are the most efficient and cost-effective way to generate clean, renewable energy from the sun. PV solar cells are made of semiconductor materials, such as silicon, which convert sunlight directly into electricity. PV solar cells are typically used on rooftops to power homes and businesses, but can also be used in large-scale solar farms to generate electricity for entire communities. When a semiconductor is exposed to light, the light's energy is absorbed and transferred to the semiconductor's negatively charged electrons. The additional energy enables the electrons to conduct an electrical current through the material. PV solar cells require no fuel, no moving parts, and no emissions, making them a clean and sustainable source of energy. They are also relatively easy to maintain and have a long lifetime of over 25 years. PV solar cells are becoming increasingly popular with homeowners, businesses, and communities around the world as a way to reduce their energy costs and reduce their carbon footprint. With advancements in technology and cost reductions, PV solar cells are becoming even more accessible and affordable for everyone [24].

Figure 3.15: Photovoltaic panel.

3.4.10 LED Strip

The WS2812B LED strip is a 5 volt addressable RGB LED strip; it comes with unique chips that let controlling control a single LED or a group of LEDs. Addressable refers to the additional provision that allows control over a particular portion of the strip. Containing an integrated circuit (IC) in them makes one-wire interface communication possible. This implies that user can use one Arduino digital pin to control many LEDs. User can control the LED by changing the colors, brightness, and timing of numerous effects. [25].

Figure 3.16: WS2812 LED strip.

3.4.11 Lithium-ion Battery

Lithium ion batteries have become increasingly popular for use in solar energy systems for a variety of reasons. Lithium ion batteries are known for their high energy density, allowing them to store more energy than other types of batteries. That means that a lithium ion battery system can store more energy than other types of batteries, allowing it to provide more energy to your home or business. They also have a longer lifespan, typically lasting up to 10 years or more, making them significantly more reliable and cost-effective than other types of batteries. In addition, they require less maintenance than other types of batteries, making them a great choice for homeowners and businesses who want to save money and time in the long run. Finally, lithium ion batteries are lighter and more compact than other types of batteries, making them easier to install in hard-to-reach places such as attics and basements. With all of these benefits, it’s easy to see why lithium ion batteries have become increasingly popular for use in solar energy systems.

The energy density of lithium-ion is typically twice that of the standard nickel-cadmium. There is potential for higher energy densities. The load characteristics are reasonably good and behave similarly to nickel-cadmium in terms of discharge. The high cell voltage of 3.6 volts allows battery pack designs with only one cell. Most of today's mobile phones run on a single cell. Lithium-ion is a low maintenance battery, an advantage that most other chemistries cannot claim. There is no memory and no scheduled cycling is required to prolong the battery's life. In addition, the self-discharge is less than half compared to nickel-cadmium, making lithium-ion well suited for modern fuel gauge applications. Lithium-ion batteries need a protection circuit to restrict each cell's max charging voltage and avoids too low discharge voltage. The cylindrical 18650 lithium-ion battery shown in Figure 3.17 is the most cost-effective lithium-ion battery in terms of energy density. Mobile computing and other applications that do not require ultra-thin geometry employ this cell. The prismatic lithium-ion battery is the best option if a small pack is required. In terms of stored energy, these cells are more expensive [26].

Figure 3.17: Lithium-ion battery.

3.4.12 USB 3S Charger

One of the main benefits of the 3s lithium battery charger is its ability to charge multiple batteries at once. The '3s' in the name refers to the number of cells that the charger can handle, which is three. This is useful for devices that use lithium batteries, such as drones, cameras, or even electric vehicles. The 3s lithium battery charger also has various safety features to ensure the batteries are charged safely and efficiently. These chargers have built-in protection against overcharging, over-discharging, and short-circuiting. Overcharging a lithium battery can cause it to overheat and potentially catch fire, so this safety feature is crucial. Additionally, over-discharging a lithium battery can damage it and reduce its lifespan. The input voltage is 5V DC, and charging voltage is 12.6V [27].

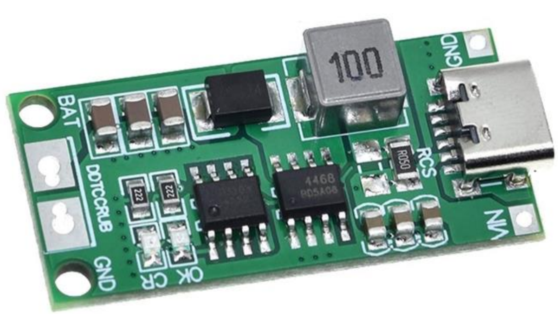

Figure 3.18: USB 3S Charger.

3.4.13 (3S) Protection Board

The Li-ion battery protection board is designed to prevent overcharging, overdischarging, short circuit, and overcurrent, all of which compromise the battery pack's safety. The board is designed for a 3-cell lithium-ion battery pack. The 18650 protection board is designed especially to work with lithium battery packs that have a voltage of 11.1V, guaranteeing compatibility and best results. The 18650 battery charger circuit consumes very little power with a quiescent current less than 30uA, making the battery system more efficient overall. While its maximum discharge current is 10 A [28].

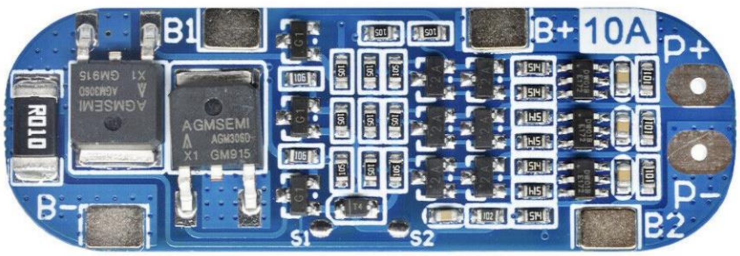

Figure 3.19: (3S) Protection Board.

3.4.14 Boost Converter (MT3608)

MT3608 2A step-up converter which means it takes a low input voltage and increases it to a higher output voltage. It can accept input voltages as low as 2V. It can boost the output voltage as high as 28V. The module automatically shifts to pulse frequency modulation mode at light loads. This is a power-saving feature that improves efficiency when the load is low. One of its features is under-voltage lockout which prevents the converter from operating when the input voltage is below a certain threshold. It also has a thermal overload protection which protects the module from overheating by shutting down if the temperature exceeds a certain limit. This type of module can be useful in various electronic projects where a stable and higher voltage supply is needed from a lower voltage source, such as in battery-powered applications or when powering circuits that require higher voltage than the available power source [29].

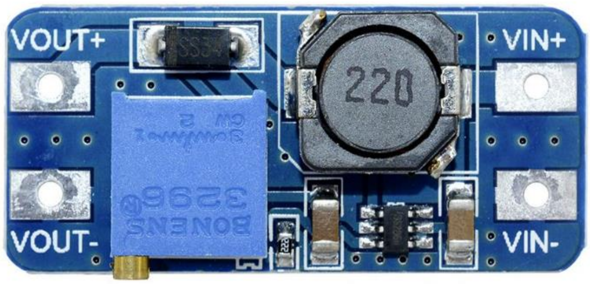

Figure 3.20: MT3608 step-up converter.

3.4.15 Buck Converter (LM2596)

This step-down power module, the LM2596S DC to DC Buck Converter, has an adjustable voltage range and is very efficient at driving loads up to 3A. Heat sinks must be added when using this module at current levels over 2.5A (or with output powers larger than 10W) in order to prevent overheating. These devices come with 3.3 V, 5 V, 12 V fixed output voltages as well as an adjustable output version. Because the LM2596 series switches at 150 kHz, fewer filter components are possible than with switching regulators that operate at lower frequencies [30].

Figure 3.21: LM2596 Buck converter.

3.4.16 Arduino IDE Software

The Arduino IDE (Integrated Development Environment) is a great way to get started with coding and hardware development. It is a cross-platform, open source environment that is designed to make it easy to write code, upload it to the Arduino board, and begin to interact with the physical world. The IDE includes a text editor for writing code, a message area, a console, a toolbar with buttons for common functions, and also a series of menus. With the Arduino IDE, you can write sketches (the name for Arduino code files) and upload them to your board. You can also use it to open existing sketches, run them on your board and edit them. Arduino IDE is the most popular and widely used platform for programming Arduino microcontrollers. It is user-friendly and provides a simple and intuitive interface for programming. The IDE is written in Java and provides an extensive set of libraries and tools that make it easy to develop programs for Arduino boards. It also offers a lot of support for new users, with tutorials, forums, and other resources to help users get started. Arduino IDE is also flexible, allowing users to write programs in C and C++ making it an ideal platform for a wide range of projects. The Arduino language makes it very easy to get started with coding and hardware development, as it is designed to abstract away some of the more complex aspects of programming. Additionally, Arduino IDE supports a wide range of Arduino boards, including the popular Uno, Mega, and Nano boards. With Arduino IDE, users can quickly and easily program their Arduino boards and create amazing projects [31].

3.4.17 MIT App Inventor

MIT App Inventor is an online platform for developing apps for Android devices. This platform is easy to use and enables users to drag and drop interface components and allow them to easily create functioning apps. It is designed with a blocks-based programming language, which allows users to create apps without having to learn a complex coding language. Users can create apps with interactive elements such as buttons, text boxes, and image galleries. In addition, they can also add components for storing data, sending and receiving data from web services, and communicating with other Android devices. The platform also allows users to customize their apps with a variety of features such as text-to-speech, location awareness, and even augmented reality. With this platform, users can quickly and easily create useful and engaging apps for Android devices [32].

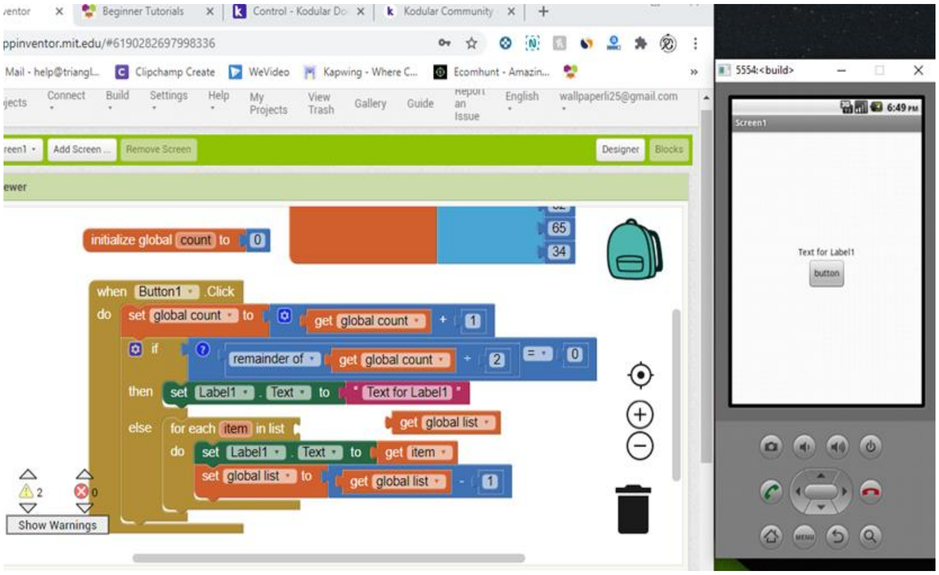

Figure 3.22: MIT App Inventor.

3.5 Budget

The project’s cost is listed below in Table 3.1.

Table 3.1: Cost of hardware components.

Item Description	**Qty.**	**Cost – KWD/each**
Arduino Nano	1	8
Ultrasonic sensor (US-016)	1	3
Line tracking sensor (TCRT5000 Infrared Reflective sensor)	1	2
DC gear motor with wheel	2	6
Motor drive (L293D)	1	4
NFC reader and tags (NFC PN532)	1	8
Buzzer	1	1
LED	2	1
Bluetooth module (HC-06)	1	3
Servo Motor	1	5
Solar Panel – PV (6v, 3watt)	2	4
Battery Charger	1	4
Lithium-ion Battery (3.7v)	3	6
Protection board	1	3
Boost converter	1	2
Buck converter (LM2596)	2	2.15
Box	1	7
Cart prototype requirements		11
		105.3

3.6 Analysis

NFC tag will be tagged to the items. When the system is turned on and the user starts adding items to the cart by scanning the item's NFC tag by the NFC reader, the item's details will be sent to the Arduino Nano which will send these details to the tablet via Bluetooth to be shown on the Android application GUI. At this time, the Arduino turns on the red LED as an indication that the customer didn't pay the bill yet. When the user finishes shopping and wants to pay, he should use the android application by pressing check out button. Then, he should follow all the steps of paying the bill. When the cashier releases the cart, the Arduino turns on the green LED. After that, if he wants to deliver the cart to the car by inserting the parking lot number, the Arduino will give an order to the up/down servo motor to rotate to the position that pulls the DC motors and the wheels down which results in pushing the rare wheels of the cart up. Then the IR line tracking sensors will detect the path line and follow it with the help of the ultrasonic sensor which will be used for detecting objects and obstacles when the cart is moving automatically to avoid collisions, while the buzzer will be used to start a an alert sound when an obstacle is detected.

3.7 Ethics and Limitations

The fundamental goal of the project's conception, design, and execution is to guarantee that the system's development and application won't pose risks to people and society, and that it will benefit the nation as a whole because the project is intended to be utilized for a variety of purposes. Additionally, we will consider the IEEE standards throughout the entire process.

As limitations, Arduino programming and developing Android applications for the first time can be challenging and time consuming. Since the system will use PV cells for charging the lithium-ion batteries, the PV cells efficiency their efficiency and output can be affected by weather conditions; on days with high temperatures, the cells may overheat and thus reduce their efficiency. Also, on cloudy days, the amount of light that reaches the cells is not enough to generate the necessary amount of electricity. Furthermore, on days with strong winds, the cells may not be able to generate enough energy as the wind can cause them to vibrate, thus decreasing their efficiency. Additionally, PV cells are also affected by dust and dirt, as a layer of dirt can block the light from reaching the cells. Thus, it is important to keep the cells clean in order to ensure that they are able to generate the maximum amount of energy.

Chapter 4 : IMPLEMENTATION

4.1 Introduction

This chapter introduces the system hardware implementation supported with schematic circuits, software implementation introducing how the Arduino was programmed, the data was written to the NFC tags, and how the mobile application was developed. It also introduces the IEEE standards followed by the project.

4.2 Hardware Implementation

The system is powered by three 3.7v lithium ion batteries. The batteries are connected together in serial, so the summation of their voltage is 11.1v and the maximum voltage is 12.6v. The protection board has the labeled terminals for B-, B1, B2, B+, P-, and P+. The positive terminal of the first battery is connected with B+ of the protection board. The positive terminal of the second battery is connected with B2. The positive terminal of the third battery is connected with B1. The negative terminal of the third battery is connected with B-. The motors need 12v to operate, then they are connected to the protection board output pins (P+ and P-). The positive terminal of the charger is connected to P+ of the protection board, and the negative terminal of charger is connected to the P- of the protection board. The solar panels used in this project are (6V, 3w), and they are connected in parallel. Since the 6v is not enough to charge the 3 batteries, then a boost converter is used to step the voltage to 12.6v needed to charge the batteries. The positive terminal of the solar panels is connected with the boost converter positive input pin (IN+), and the negative terminal of the solar panels is connected with the boost converter negative input pin (IN-). The output pins of the boost converter are connected with the protection board pins (P+) and (P-). To get the required voltage to power the system components which is 5v, a buck converter is used. The input terminals of the buck converter (IN+) and (IN-) are connected with the protection board output pins (P+) and (P-). Another buck converter is used to step down the voltage to 5v to power the servo motor; because it's considered as a heavy load that requires high power. The switch is used for turning the system on and off.

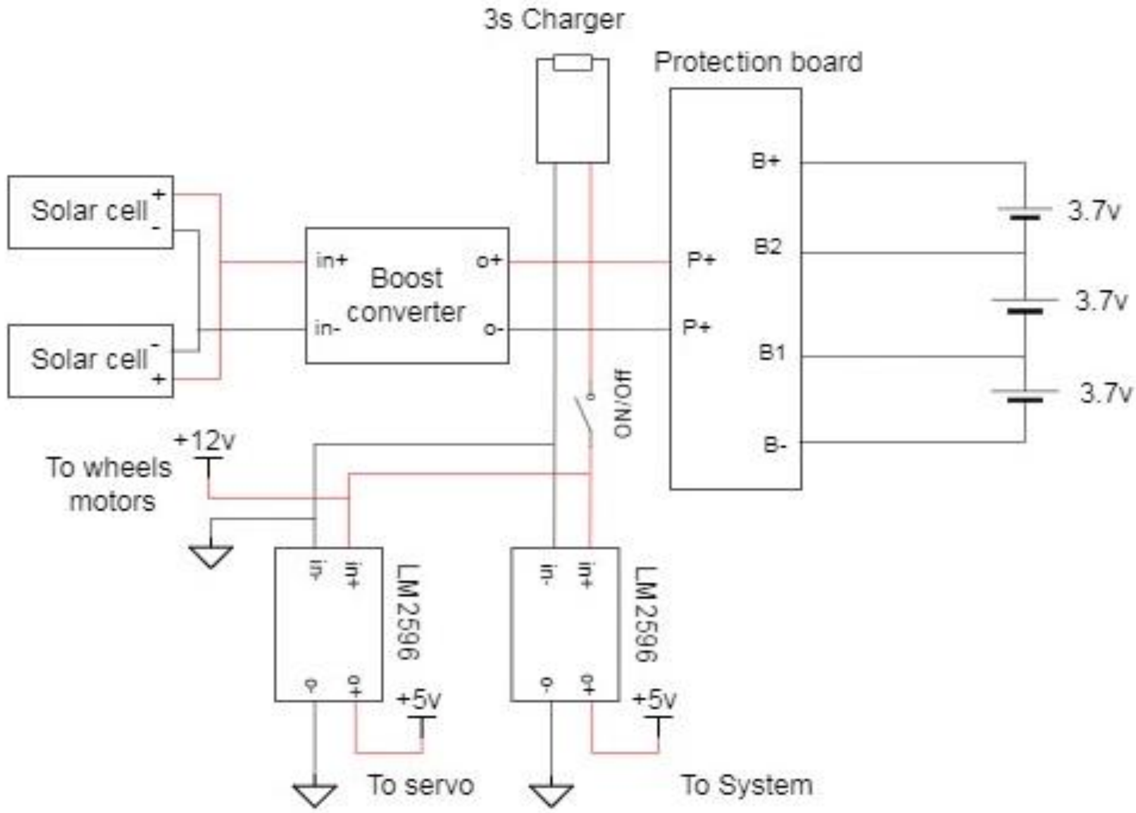

Figure 4.1: Power supply schematic circuit.

To interface the US-016 ultrasonic sensor with an Arduino Nano, there are a few simple steps that need to be followed. The first step is to connect the VCC and GND pins of the sensor to the 5V and GND pins of the Arduino Nano respectively. Next, the OUT pin of the sensor is connected to the Arduino analog pin A0. The three IR sensors VCC pins are connected to the 5V pin on the Arduino, the GND pins to the ground pin, and the OUT pins to the Arduino's pins A3, A2, and A1. The TCRT5000 sensor consists of an infrared emitter and receiver, both housed in a compact package. The emitter emits an infrared beam towards the target object, while the receiver detects the reflected beam. This reflected beam is then converted into an electrical signal, which can be read by the Arduino Nano. The Nano's serial port is used to establish a communication link between the Nano and the HC-06 through the use of serial communication protocol. The Nano communicates with the HC-06 through two digital pins, one for transmitting and one for receiving data. TXD pin of the HC-06 module is connected to D2 pin whereas the RXD pin is connected to the D4 pin. Its VCC pin is connected to the 5V pin on the Arduino, and the GND pin to the ground pin. The PN532 reader and the Arduino Nano are connected via the I2C interface, which is a serial communication protocol that allows multiple devices to communicate with each other using only two wires; SDA (Serial Data) and SCL (Serial Clock). The I2C interface is essential for the successful communication between the PN532 reader and the Arduino Nano. The PN532 reader utilizes the I2C protocol as its primary means of communication, making it the ideal interface to use with the Arduino Nano. This interface allows for bi-directional communication between the two devices, allowing the Arduino Nano to send commands to the PN532 reader and receive data back from it. To establish a connection between the PN532 reader and the Arduino Nano through the I2C interface, the SDA and SCL pins of the PN532 reader are connected to the corresponding pins on the Arduino Nano; A4 and A5. The module's VCC pin is connected to the 5V pin on the Arduino, and the GND pin to the ground pin. To power the L293D board, its VIN pin is connected to the 12V provided by the three batteries, while the GND pin is connected to the ground. The four input pins of the motor driver chip, IN1, IN2, IN3, and IN4, are connected to digital pins 3, 5, 6, and 11 on the Arduino Nano, respectively. The board has four motor driver channels, each of which can be connected to a separate DC motor. One of the DC motors is connected with A+ and A- pins, while the other is connected with B+ and B- pins. To change the direction of the motor, the IN pins are used. By setting the IN pins to HIGH or LOW, the motor can be made to rotate in either direction. Setting IN1 to HIGH and IN2 to LOW will make the motor rotate in one direction, while setting IN1 to LOW and IN2 to HIGH will make it rotate in the opposite direction. The same method for controlling the other DC motor. To provide power to the servo motor, the red wire is connected to the 5V pin of the Arduino Nano. The ground wire is connected to the ground, and the signal wire is connected to the Arduino's pin D8. The LED strip has three connectors, one is connected to 5v, one is connected to the ground, and the third is connected with the Arduino's digital pin D9. The buzzer is connected to the Arduino's pin D7, while the other leg is connected to the ground.

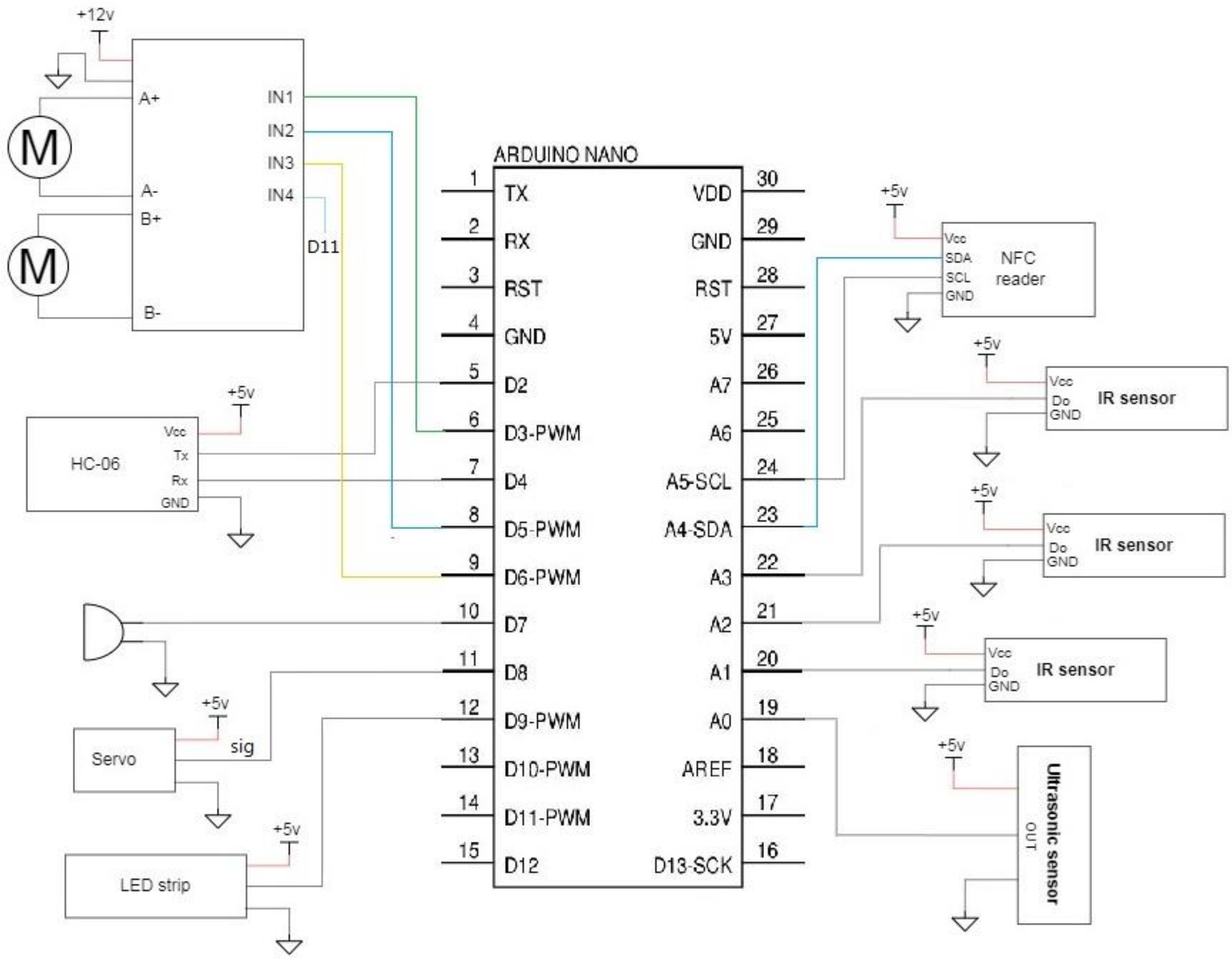

Figure 4.2: Components implementation schematic circuit.

Figure 4.3 shows the system design, where the components are installed in the plastic box to protect them from damage. It also shows how the solar panels are installed.

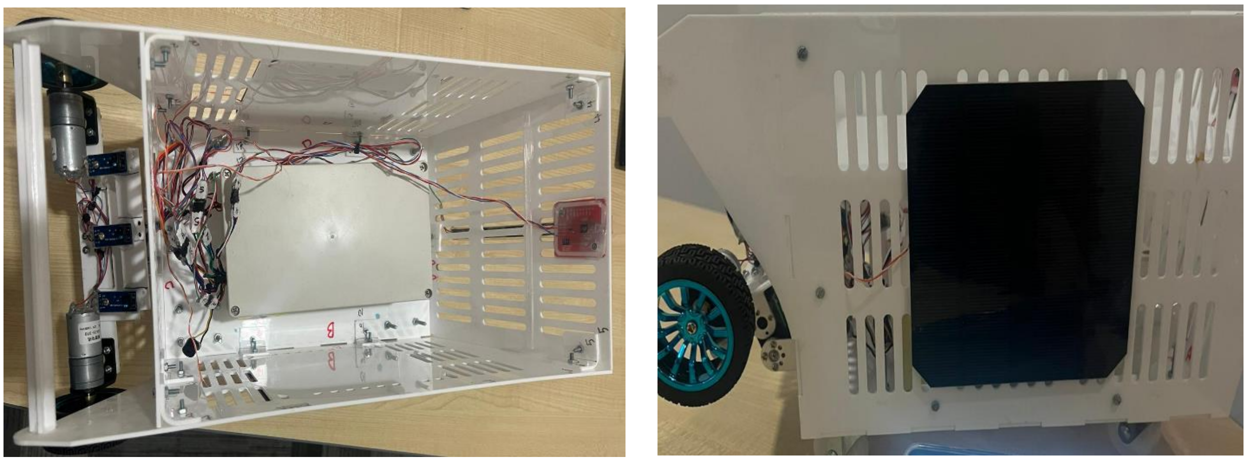

Figure 4.3: System design.

4.3 Software Implementation

4.3.1 Arduino Programming

One of the main advantages of using the Arduino Nano is its compatibility with the C language. C is a widely used programming language that is known for its efficiency, speed, and versatility. This makes it an ideal choice for creating complex and resource-intensive projects on the Arduino Nano. The Arduino IDE provides a simplified and user-friendly interface for writing C code, making it accessible to both beginners and experienced programmers. The Arduino IDE also has a vast community of users and developers who share their projects, code, and knowledge. This community provides a valuable source of support and inspiration for those new to Arduino programming or looking to expand their skills. With the help of this community, users can easily troubleshoot any issues they encounter and learn new techniques and approaches to programming the Arduino Nano. In addition to its user-friendly interface and vast community support, the Arduino IDE also offers a wide range of debugging tools. These tools help users identify and fix errors in their code, making the programming process more efficient and less time-consuming. By providing real-time feedback and highlighting potential issues, these debugging tools enable users to write more robust and error-free code.

Here are the steps to follow for programming an Arduino Nano in the Arduino IDE using the C language:

Step 1: Arduino IDE installation

The first step is to download and install the Arduino IDE from the official website. The IDE is available for Windows, Mac, and Linux operating systems. Once the installation is complete, we should open the IDE.

Step 2: Connecting the Arduino Nano to the computer

We have connected the Arduino Nano to the computer using a USB cable. The USB cable allows for communication between the board and the IDE.

Step 3: Selecting the board and port

In the Tools menu of the IDE, we have selected the Arduino Nano under the Board menu. Then, we have selected on which USB port the board is connected to the computer.

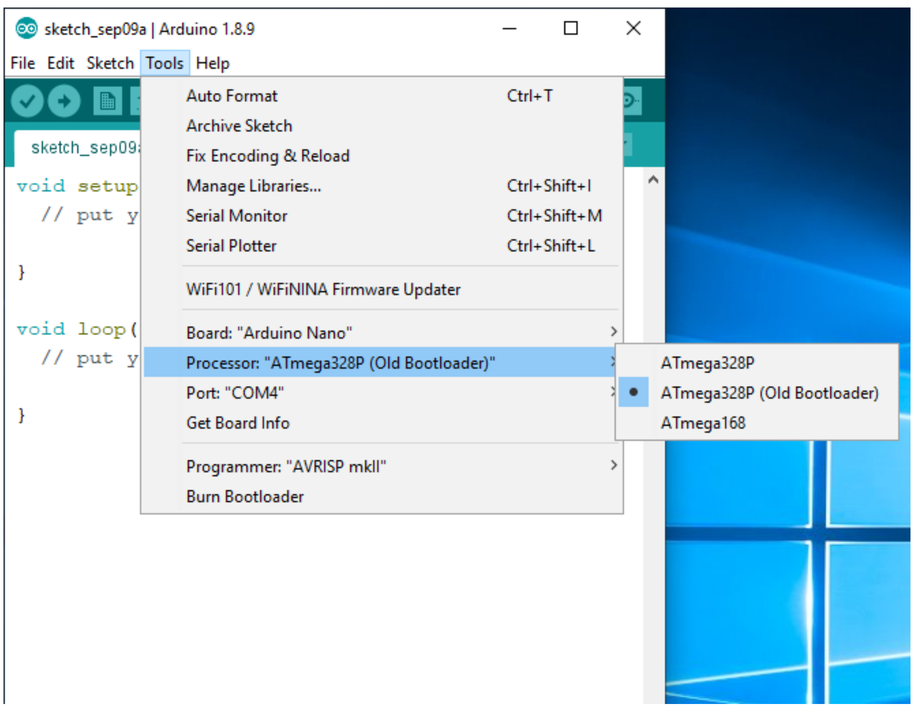

Figure 4.4: board selection.

Step 4: Writing the code

We have opened a new sketch and written the code using C language.

Step 5: Verifying the code

Before uploading the code to the board, we had to verify that there are no errors by clicking on the 'Verify' button, and the IDE will check the code for any syntax errors.

Step 6: Uploading the code

Once the code has been verified, it's time to upload it to the board by clicking on the 'Upload' button, and the IDE will compile the code and upload it to the Arduino Nano.

Step 7: Testing the code

After the upload is completed, we have tested the code by opening the Serial Monitor from the Tools menu. The Serial Monitor allows to send and receive data from the board, which is helpful for debugging the code.

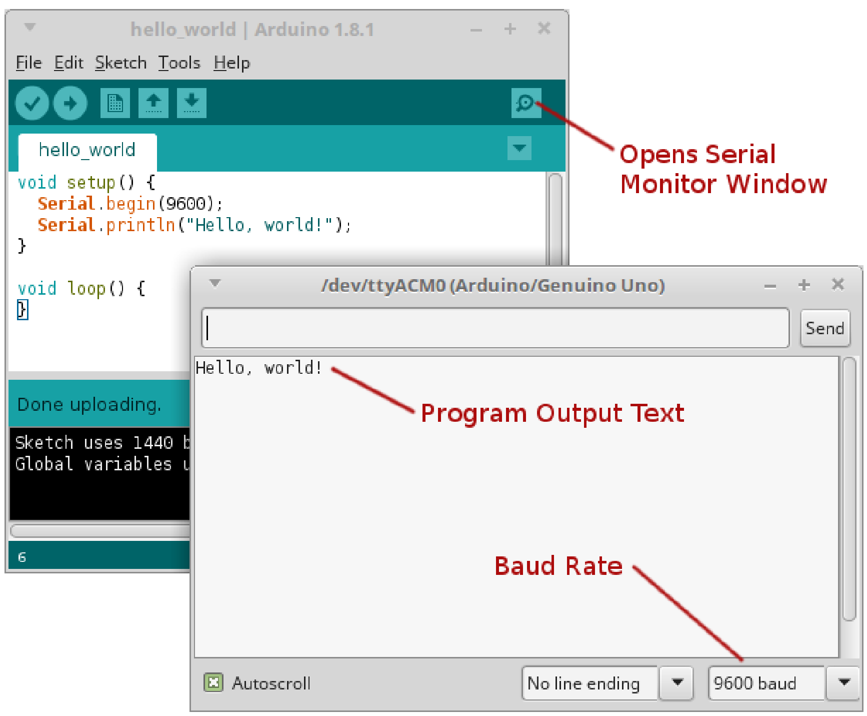

Figure 4.5: Arduino serial monitor.

4.3.2 NFC Tools

NFC tools mobile app, which allows users to write data to NFC tags directly from their mobile devices. This app offers a user-friendly interface, making it simple for anyone to use, even without prior technical knowledge. In addition to writing data to NFC tags, the NFC tools mobile app also allows users to read and analyze the information stored on the tags. The application interface is shown in Figure 4.6. To write data on the NFC tag, we should tap on "Write" list, then choose "add a record". Once we write the needed data, we should tap "ok"

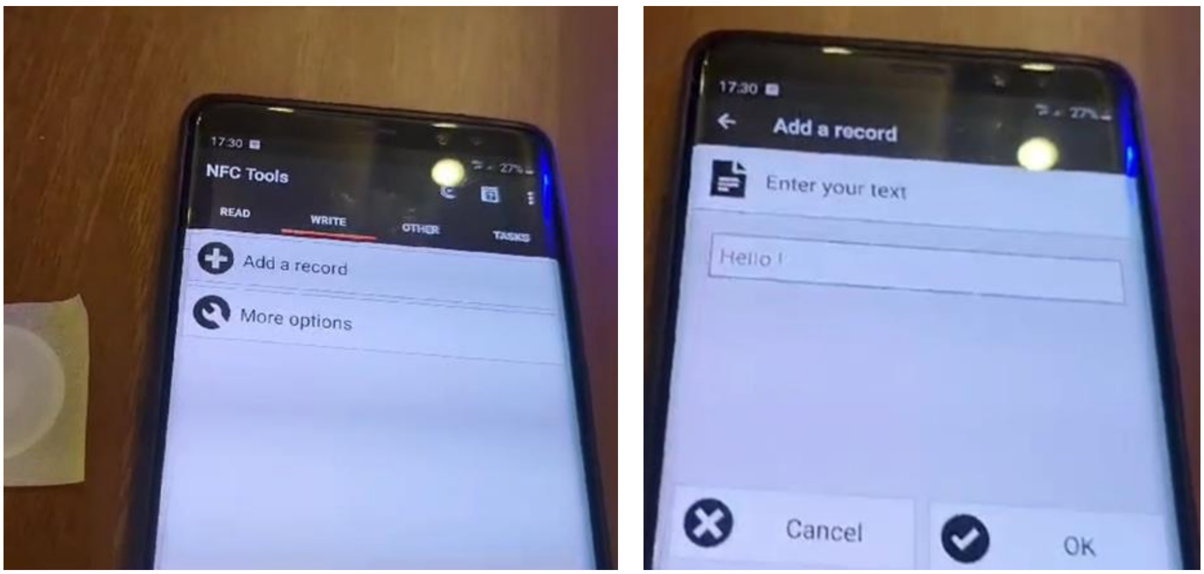

Figure 4.6: NFC Tools app.

Then, we should select “write” option. The application will display “approach an NFC tag” as shown in Figure 4.7. Once we approach the mobile on the NFC tag, data will be written on the tag and the application shows a confirmation “write complete.”

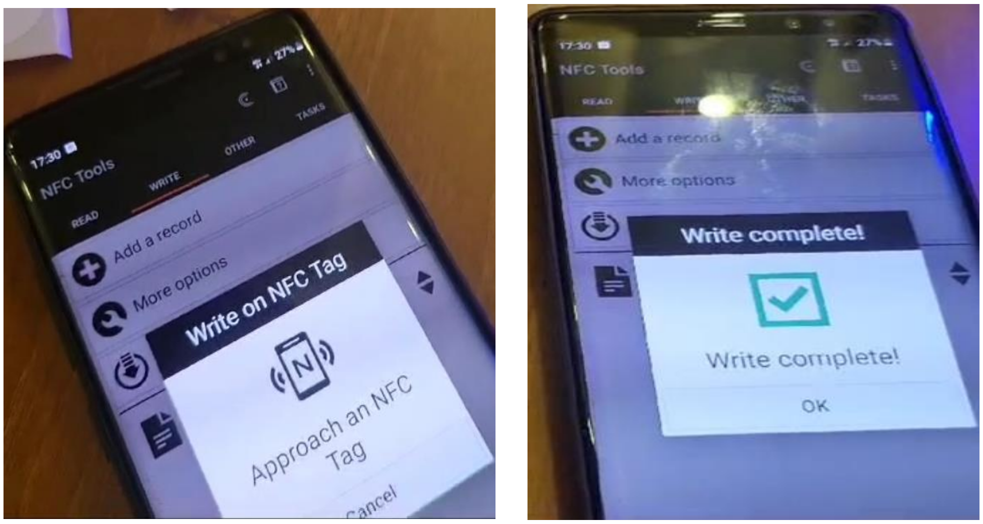

Figure 4.7: Writing data to NFC tags instructions.

4.3.3 Android Mobile Application

MIT App Inventor is a drag-and-drop interface that allows users to create their own android mobile applications without any prior coding experience. The app is built using a block-based coding system, where users can drag and drop different blocks of code to create the desired functionality. Figure 4.8 shows the main GUI of the developed Android mobile application.

Figure 4.8: Android mobile application main GUI.

4.4 IEEE Standards

- ISO/IEC 18092 (Near Field Communication Interface and Protocol): This ISO standard covers the near field communication interface and protocol, providing guidelines for peer-to-peer data exchange between NFC-enabled devices. The electrical properties of two different contactless interface types between a proximity card and a proximity coupling device are included in this standard. Bidirectional communication and power are also features of the interface. It is meant to be utilized in combination with further ISO/IEC 14443 series components [33].
- ISO/IEC 9899 (C Language Standard): This is the international standard that defines the C programming language. It includes syntax rules, data types, and standard libraries. Adhering to this standard ensures code portability and compatibility. This standard is important to our project due to programming the Arduino board using C language [34].
- IEEE 802.15.1 is a standard for Wireless Personal Area Networks (WPANs) that provides a framework for Bluetooth operation within the 2.4 GHz ISM band. This standard helps ensure coexistence and interoperability between Bluetooth and other wireless technologies. Since our system relies on Bluetooth connectivity between the hardware and the Android application on the tablet, this standard is essential for ensuring compatibility and coexistence between Bluetooth devices together.
- IEC 62133 - Safety Requirements for Portable Lithium-Ion Batteries: While not an IEEE standard, IEC 62133 is an international standard that outlines safety requirements for portable lithium-ion batteries, which include those of the 18650 form factor. Since our system should be portable, it is powered by 18650 lithium-ion batteries.

Chapter 5 : EVALUATION

5.1 Introduction

This chapter introduces how the system works in details showing the overall system testing and results. The project considerations are also included.

5.2 How the System Works

Figure 5.1 shows the mobile application GUI that can be used for testing the system working (by tapping on test button”.

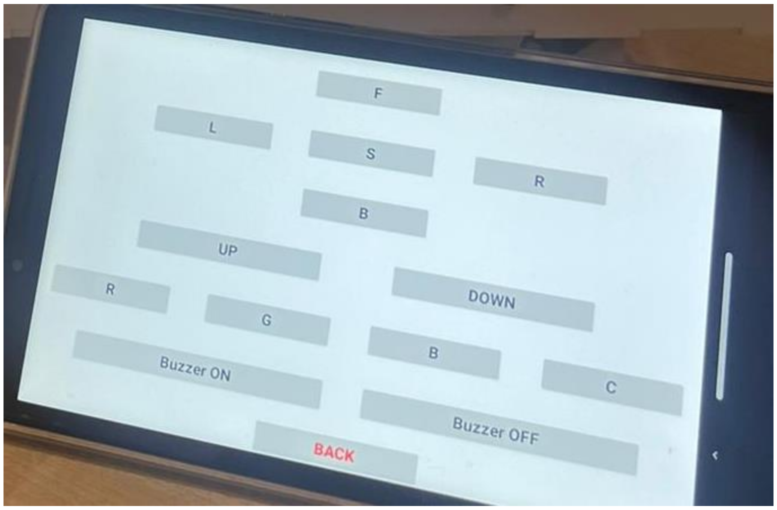

Figure 5.1: mobile application GUI for testing the system.

Once the user starts the shopping, the GUI appears as shown in Figure 5.2; where the added items details will be shown.

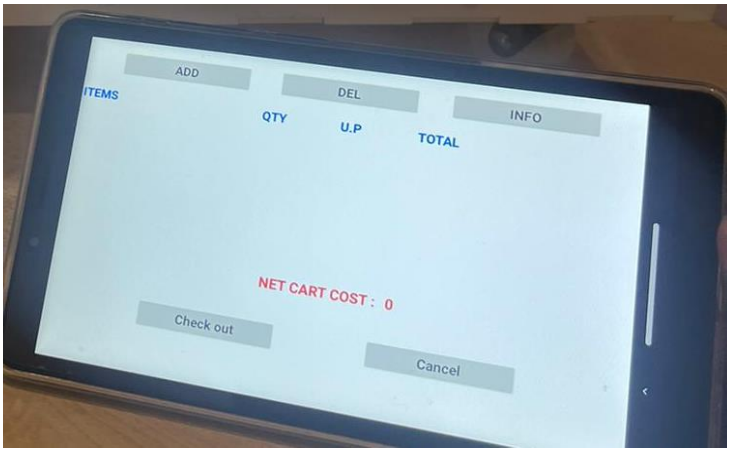

Figure 5.2: mobile application default GUI when shopping is started.

Figure 5.3 shows how the user should scan the item's NFC tag to add it to the bill.

Figure 5.3: NFC tag scan by NFC reader.

Figure 5.4 shows the application GUI of the purchase bill when an item is added to the cart by scanning its NFC tag.

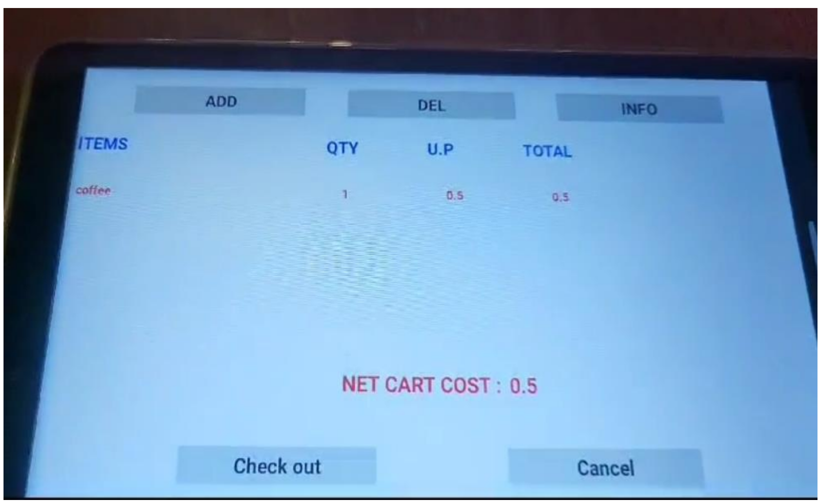

Figure 5.4: Purchase bill details.

Figure 5.5 shows the GUI when the user presses “check out”. To complete the payment, he should press “pay”.

Figure 5.5: payment completion.

Figure 5.6 shows GUI when the user completes his payment, and give him the option to select the parking number needed. Then, he should press “start” to let the cart goes to the needed parking number by itself.

Figure 5.6: car parking number selection.

Once it reaches the selected parking, the user can remove the items form the cart then press “go home”; then it moves automatically to the place where the carts are placed. When it reaches there with the help of the IR and ultrasonic sensors, the buzzer will be on until the user presses “done”.

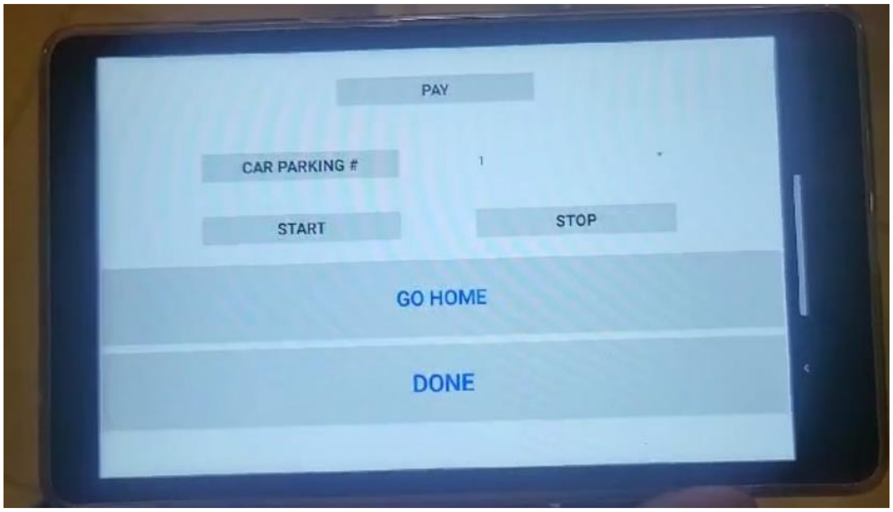

Figure 5.7: go home option.

5.3 Project Considerations

In terms of social considerations, smart shopping carts promote a more efficient and convenient shopping experience for customers. With features like built-in scanners and touchscreens, shoppers can easily locate and scan items, eliminating the need to search for products or wait in long checkout lines. This can be particularly beneficial for individuals with disabilities or those who may have difficulty navigating in a store. Furthermore, these carts can also help reduce stress and frustration for busy parents or individuals with limited time, allowing them to quickly and easily complete their shopping.

From a manufacturing perspective, the use of NFC technology in shopping carts can lead to the creation of more advanced and sophisticated carts. These carts can be equipped with sensors, screens, and other components that enable them to communicate with customers' devices and provide a better shopping experience. This would lead to an increase in the demand for these carts, resulting in more manufacturing jobs and economic growth.

In terms of economic impact, the use of NFC technology in shopping carts can lead to increased efficiency and convenience for customers. With the ability to add items to their cart with a simple scan, customers can save time and effort during their shopping trips. This can lead to an increase in customer satisfaction. In addition, the designed system can create a bill on customer’s mobile application, which would make it easy for him to pay his bill easily, allowing him to improve his purchasing activity.

Chapter 6 : CONCLUSIONS AND FUTURE WORK

6.1 Conclusion

The project seeks to address the issue with conventional shopping carts by designing a system that can be added to the cart to make it smart and prevent wasting time and effort while waiting in line to pay for purchases,. Additionally, it will remove the need to drag the heavy cart out into the parking lot in order to load the purchased items into the vehicle. As a result, we have developed an Arduino-based system that consists of three primary components: electronic, an Android application, and wireless communication between the system’s controller and the Android application. The user can interact with the cart's system through the Android application by adding, deleting, and searching for products. When the user wants to check out, he can use the application to display the purchase list and pay the purchasing bill. The cart functions in two ways: in the manual mode, the customer pushes the cart. In the automatic mode, the cart will move by itself into a specific path by using line-following sensors and an obstacle detection sensor to identify obstacles in its path and direct it toward the parking lot where his car is parked.

6.2 Future Works

Many features can be added to the system such as:

1. We can add a camera to enable the cart to follow the customer inside the market.
2. Motors can be added to move the solar cells when the cart is used outdoor.
3. We can use more batteries.
4. We can add a GPS module to track the cart in the market, and enable the cart to move to the place where carts are gathered instead of line following.

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APPENDIX A

Gantt chart.

Task	**September**				**October**				**November**				**December**			
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15	W16
Hardware Components ordering																
Building the Hardware																
Android Application development																
Arduino programming																
System testing and evaluation																
Report 2																

APPENDIX B

- ## Arduino codes

Initialization procedures

```
#define rmf 3

#define rmb 5

#define lmf 11

#define lmb 6

#define rs A3

#define cs A2

#define ls A1

#define buzzer 7

#define PIN 9

#define NUMPIXELS 11

#define uss A0


SoftwareSerial bts(2, 4);

Servo ss;

Adafruit_NeoPixel pixels(NUMPIXELS, PIN, NEO_GRB + NEO_KHZ800);

PN532_I2C pn532_i2c(Wire);

NfcAdapter nfc = NfcAdapter(pn532_i2c);
```

Setup procedures

```
void setup() {

Serial.begin(9600);

pinMode(rmf,OUTPUT);

pinMode(rmb,OUTPUT);
```

```
pinMode(lmf,OUTPUT);
pinMode(lmb,OUTPUT);

pinMode(buzzer,OUTPUT);

pinMode(rs,INPUT);
pinMode(cs,INPUT);
pinMode(ls,INPUT);

digitalWrite(buzzer,1);
ss.attach(8);
spos=180;
ss.write(spos);
delay(500);
bts.begin(9600);
m_stop();
digitalWrite(buzzer,0);
pixels.begin();
pixel_blue();
nfc.begin();
}//setup
```

Receiving commands from bluetooth

```
if (bts.available()){
  rxx=bts.readString();
}
pos1=rxx.indexOf("FORWARD");
if (pos1>=0){
m_for();
}
```

```
pos1=rxx.indexOf("RSTOP");
if (pos1>=0){
m_stop();
}

pos1=rxx.indexOf("BACK");
if (pos1>=0){
m_rev();
}
pos1=rxx.indexOf("RIGHT");
if (pos1>=0){
m_rig();
}
pos1=rxx.indexOf("LEFT");
if (pos1>=0){
m_lef();
}
pos1=rxx.indexOf("UP");
if (pos1>=0){
servo_up();
}
pos1=rxx.indexOf("DOWN");
if (pos1>=0){
servo_down();
}
```

Read from NFC

```
void read_nfc(){
      NfcTag tag = nfc.read();
    NdefMessage message = tag.getNdefMessage();
    NdefRecord record = message.getRecord(0);
    record.getPayload(fdat);
     bts.println(fdat);
digitalWrite(buzzer,1);
delay(100);
digitalWrite(buzzer,0);
}//void
```

Line following procedure

```
void black_line_follow(){
rv=digitalRead(rs);
lv=digitalRead(ls);
cv=digitalRead(cs);
distance=analogRead(uss);
if (distance<200){
 m_stop();
 buzz();
}
if ((rv==1)and(lv==1)and(cv==1)){//all see black
  car_num-=1;
  if (car_num==0){m_stop();buzz();buzz();
  }else{
  bts.print("remaining ");bts.println(car_num);
  buzz();
  }
```

```
}
if ((rv==1)and(lv==0)and(cv==0)){//right see black
  m_rig();
  delay(100);
  m_stop();
}
if ((rv==0)and(lv==1)and(cv==0)){//left see black
  m_lef();
  delay(100);
  m_stop();
}
if ((rv==0)and(lv==0)and(cv==1)){//center see black
  m_for();
}
  }//line follow
```

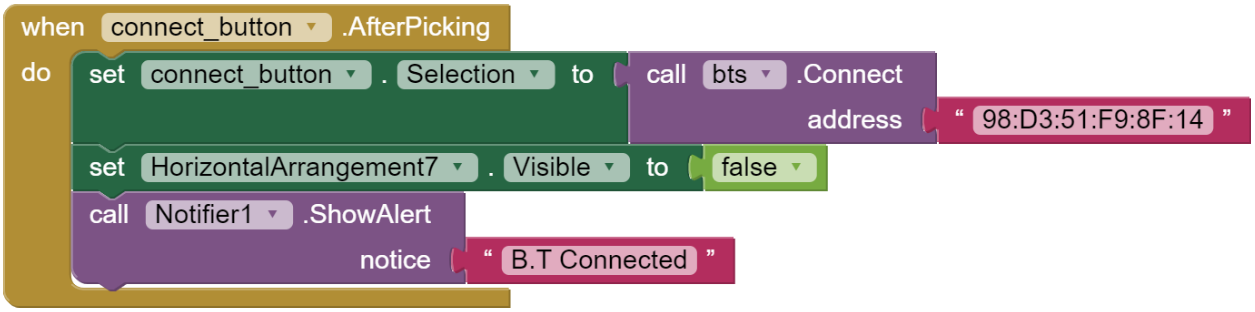
Motors control

```
void m_stop(){
analogWrite(rmf,0);
analogWrite(rmb,0);
analogWrite(lmf,0);
analogWrite(lmb,0);
}
void m_for(){
analogWrite(rmf,spd);
analogWrite(rmb,0);
analogWrite(lmf,spd);
analogWrite(lmb,0);
}
```

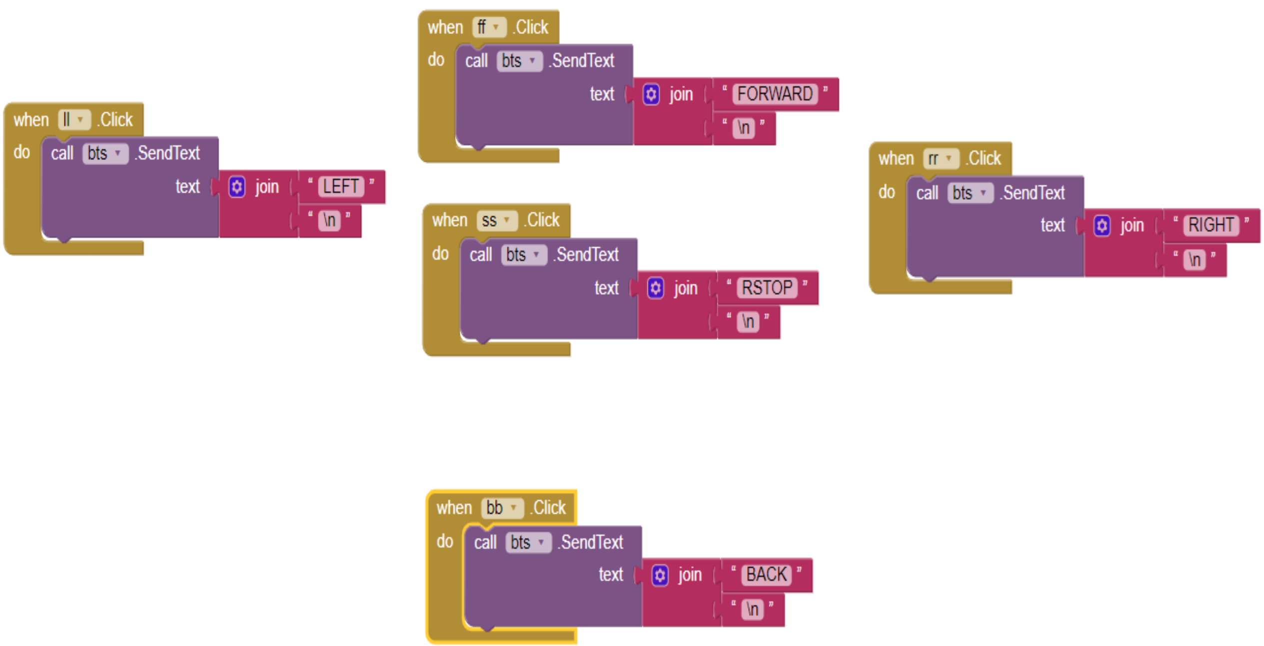
```
void m_rev(){
analogWrite(rmf,0);
analogWrite(rmb,spd);
analogWrite(lmf,0);
analogWrite(lmb,spd);
}
void m_rig(){
analogWrite(rmf,0);
analogWrite(rmb,spd);
analogWrite(lmf,spd);
analogWrite(lmb,0);
delay(150);
analogWrite(rmf,0);
analogWrite(rmb,0);
analogWrite(lmf,0);
analogWrite(lmb,0);
}
void m_lef(){
analogWrite(rmf,spd);
analogWrite(rmb,0);
analogWrite(lmf,0);
analogWrite(lmb,spd);
delay(150);
analogWrite(rmf,0);
analogWrite(rmb,0);
analogWrite(lmf,0);
analogWrite(lmb,0);
}
```

MIT BLOCKS

Bluetooth connection



Direction control



Receiving data from Arduino