SASC

Self-Assistive Smart Cart

SYNDICATE MEMBERS

Zain Shabbir

Najeeb Anwar Tareen

Muhammad Ahmad

SUPERVISOR

Assistant Professor Dr. Mir Yasir Umair

Submitted to the faculty of Department of Electrical Engineering, Military College of Signals, National University of Sciences and Technology, in partial fulfillment for the requirements of B.E Degree in Electrical Engineering

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CERTIFICATE OF CORRECTIONS & APPROVAL

It is Certified that the work presented in this following titled "SASC (SELF ASSISTIVE SMART CART)," was carried out by NC Zain Shabbir, NC Najeeb Anwar Tareen, NC Muhammad Ahmad under the supervision of Assistant Professor Dr. Mir Yasir Umair required for the partial fulfillment of the degree of Bachelor of Electrical (Telecomm.) Engineering in Military College of Signals, National University of Sciences and Technology, Islamabad during the academic year 2020-2021 does not contain errors and is accepted. Any information or material equipped from any external sources has been accurately referenced.

Approved by

Assistant Professor Dr. Mir Yasir Umair

Department of EE, MCS

Date: 30th June 2021

DECLARATION

It is hereby declared that no part of the following Thesis is written, published, nor submitted in favor of any other qualification in neither this nor any other institute.

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Zain Shabbir

219159

Najeeb Anwar Tareen

237802

Muhammad Ahmad

207632

Signature of Supervisor

بسم الله الرحمن الرحيم

We are dedicating this effort to our parents and the teachers with whose tremendous support and cooperation to reach this accomplishment.

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ABSTRACT

SASC (Self-Assistive Smart Cart) is a cart having autonomous mobility which is deployed in a capacity to perform tedious and time-consuming tasks. The cart is operated using the Beacon, which sends data serially through Bluetooth. Upon receiving the values, the cart takes necessary decisions and adjusts itself depending upon the values it receives. This feature eases the very lethargic process of shopping and makes it reward, as low human input effort is required. This would mean it is not just energy saving but furthermore time-saving.

This particular idea manufactured into a product is universal, and we shall not have to face any troubles while bringing it into the operation phase. Having other viable options to compete, **SASC** has a clear upper hand, as it sets the standard high being easily deployable, efficient, and cheap are some of the features that make it prominent in the autonomous domain.

Key Words:

BLE: Bluetooth low energy

RSSI: Received Signal Strength Indicator

IMU: Inertial Measurement Unit

Li-Po: Lithium Polymer

MPU: Motion Processing Unit

GUI: Graphical User Interface

CLI: Command Line Interface

API: Application Program Interface

LIDAR: Light Detection and Ranging

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Chapter 1

INTRODUCTION

1 INTRODUCTION

The field of engineering is not bounded as being the science of implementing, proposing, and generating. It depicts the art of portraying the thoughts and ideas in one's curious mind onto the piece of paper, designing the life-sized structures and objects from it, moreover, changing the minute spark of the neurons made to exist in mind through the power of imagination, and then furthermore towards the colossal innovations that finally leave the mankind into a state of shock and awe from its relish. The duty bestowed upon the shoulders of engineers with attributed responsibility that could be interdisciplinary; however, they are constantly in lieu of enhanced productivity which could lead to higher output. A great innovative idea to have emerged from the engineering intellect is Autonomous Mobility. The requisition of a machine to execute tasks previously carried out by human beings or to dominantly enhance the prolificity of tasks that were manually operated is expressed as Autonomous Mobility. The term self-governing can be greatly taken into as a synonym to autonomous; the latter mentions the bare substitution of labor with the machines. Autonomous mobility, however, has a greater and far more diverse overpass where the machine is integrated into a self-governing and sole decision-taking system.

1.1 Overview

Self-Assistive Smart Cart (SASC) is an innovation for outdoor comfort. It can be deployed in any domain in order to reduce human effort, making it much easier and more relaxing for him to perform his tasks. The technology is basically used in the commercial and residential sectors, but the target market of SASC is the enterprise of shopping. With, these systems we face some limitations. They must be in the proximity of a pre-determined threshold which is carefully selected given the overall dimensions of the capacity it operates in. The overall features of SASC include Price estimation, product information, obstacle avoidance.

Henceforth the existence of Tesla motor cars, the idea of autonomous mobility has been of keen interest all over the world. Since then, there have been multiple developments in this sector, decreasing the scale of this technology down to be implemented on other viable products, with the goal of higher accuracy and lower cost of implementation. Though many successful models were presented, the main problem was keeping a balance between quality, accuracy, and cost. The latest developments have included the use of the image processing domain to give a high-end result in the decision-making process in the maneuvering stage. A high-end product was also developed with state-of-the-art components used, but it was not cost-effective to be implemented on a larger scale; the mass production to reach the breakeven point displayed some gigantic figures. The technology had certainly faced a boom when different countries started developing this at a very rapid speed.

The day-to-day needs of shopping cannot come to a haul; you have to replace the consumed goods in order to sustain and maintain a balance in your household. SASC will come into play here using the forever living aesthetics of shopping and market this tradition by providing comfort to the customer. As we proceed in time and technology becomes more commonly and easily available to us human beings, SASC is another technology that would play a major role in creating an autonomous environment in the overall domain of shopping. In the past, we have seen major developing trends are people are slowly moving towards the domain of IoT, Autonomous Mobility, Machine Learning, and Big Data. If we compare these innovations, we can clearly identify that they have been overlapping each other. SASC is another example of these innovations but with minor figures.

Technology has revolutionized our lifestyle humans have become more habitual to getting tasks done with as little force as possible. The features of being effective and user-friendly are dominant. SASC resides these points as a top priority through the infusion of software and hardware to provide autonomous mobility, which helps to provide seamless service to the user regardless of the external conditions that may affect its performance.

1.2 Problem Statement

We bring the ideology of autonomous mobility down to a level where it can be used to perform tasks in a minimal environment; in the current day and age, shopping malls are full of people that are looking to buy groceries and Vegetables. A cart must be dragged around with him/her in the shop. SASC will do just that. Thereby reducing human effort and give an estimate of the position and price of various items.

1.3 Working Principle

The whole gateway of connection is based on BLE, which helps the cart to decide which route to take, the data is serially fed, and every Module receives information, processing phase acts, and transmission goes to the relevant Module next to it.

The details of the modules being considered are given below:

- HM-10
- LIDAR
- MPU-9250
- Motor Driver (L298N)
- Raspberry Pi 4
- GUI

1.3.1 HM-10

The 4.0 Bluetooth Module helps to establish wireless communication; the readings received from this helps the cart to maneuver itself. It is an essential part of the whole project; without the readings from it, the cart is blind and has no lead to follow.

1.3.2 LIDAR

It acts as a visual guide for the cart, the whole is moving, but blindly without fully calculating the trajectory of its path, the LIDAR is the obstacle detector. With the high accuracy of reading the objects in its path, it acts as obstacle avoidance, using optical sensing. The model used here is TF-MINI.

1.3.3 MPU-9250

Perhaps the most integral unit of the whole project without whom this notion of autonomous mobility is incomplete, the MPU-9250 helps to provide the turning mechanism using the IMU, which helps the cart to understand when to turn and how much degree to rotate from a certain axis.

1.3.4 Motor Driver (L298N)

This a dual H-bridge motor that helps to propel the motors, which in turn means controlling the speed, depending upon the amount of DC voltage being supplied. Furthermore, it allows the Microcontroller to control the directional control of the motors.

1.3.5 Raspberry Pi 4

The central processing unit of the whole operation, it is at the heart of all the processing phase, the 2GB variant being used helps to provide seamless performance with multiple values being calculated and all the different algorithms working [1].

1.3.6 GUI

The user-friendly interface provided as a commodity for the customers to keep them aware of all the products and the approximate cost of the whole bill. You are providing them all the basic information about the product.

1.3.7 Atmel SAM3X8E ARM Cortex-M3

This Microcontroller is responsible for commanding the motor Driver and for getting the data to form the Lidar and converting it into Distance so that it can be used for obstacle avoidance and to control the servo motor

1.3.8 ATmega328

This is a Microcontroller that is made by Atmel. This Microcontroller is responsible for the functioning of the Beacon that sends the values to the Raspberry pi.

1.4 Objective

The whole project aims to numerous objectives, which in general are ranked into two of the following categories:

- Academic Objectives
- Industrial Objectives

1.4.1 Academic Objectives:

The Academic Objectives encloses an ample range of the outcomes which are anticipated to be completed with this project and can be compactly explained as:

- Application of the theoretically developed knowledge and implementing it practically into the fundamental attributes of technology and engineering.
- A comprehensive grip on the conceptual understanding in link to the aspects of problem-solving skills for outcome-based learning.

The final aim of this project can be widely described as:

- A compact designing of the hardware of the cart
- Development of a user-friendly GUI
- Successful obstacle avoidance
- Readings from MPU-9250 to be as accurate as possible
- Flawless connection of BLE and Cart
- Barcode Scanner to merge and align with rest of the hardware

1.4.2 Industrial Objectives:

To produce SASC as a novel product in the domain of autonomous mobility, henceforth to show hassle-free functioning, being a promising idea and allowing the enterprises and companies to have SASC under the radar as their dominant choice for being cost-efficient.

1.5 Scope

The project perceives its scope at almost any shopping mart. The project is a time-saving yet efficient solution for the task of shopping which indeed is a tedious one. The user will not have to worry about dragging the Load with him; the cart will do the work for him.

1.6 Deliverables

The Following details comprise the deliverables of the Project

1.6.1 Universal Application in any Environment

SASC can be implemented in any kind of environment. There are no such limitations, and the whole idea is to provide autonomous mobility and helping the cart to move around the customer while maintaining a certain threshold of a distance from him. There are no boundaries to the operation anywhere there is a need for products being mobile SASC comes into action.

1.6.2 Control Over Touch Screen LCD

Everything being inserted into the cart will be displayed on the touch screen LCD, so the customer remains mind full of the approximate bill being generated. Its GUI is a very user-friendly and interactive one.

1.6.3 Third-Party Control

Besides the features mentioned above, the SASC database can also be monitored via the shopping mart management systems. Furthermore, any mobile phone that supports Bluetooth 4.0 can connect with the cart, and in this case, the use of the Beacon to be carried in the pocket can be neglected—providing the compatibility with connection to a third party.

Chapter 2

LITERATURE REVIEW

2. LITERATURE REVIEW

In this current world of dynamic technology, we as humans have always tried to break boundaries and have added the features of comfort, modernism, and ease into our lives. One of the newly emerged solutions in terms of technology is autonomous mobility. The amount of cohesion and comfort that this has brought in our lives is commendable. Actions are performed without the need to even lift a finger and apply physical energy into the process. The implementation of this idea into the domain of shopping, which is an everyday task, because you have to consume products in order to sustain and work, this aesthetic of shopping is an integral part of our daily lives.

2.1 Industrial and Domestic Background

Having a location in the Asia-Pacific region, Pakistan is a country where there is a large amount of import and export, the amount of shopping and the different products making their way into the Pakistani market influences people of all ages to buy the commodity. The most recent Memorandum of Understanding (MoU) between Pakistan and China, also known as the China Pakistan Economic Corridor (CPEC), will also bring business into the country; the contribution from China is said to be about 100 billion dollars by 2017. Looking at these exponential amounts of resources, this can be used as a window of opportunity.

The economy of trade of Pakistan is fluctuating due to the rate of the dollar changing every now and then; this has demotivated the common man from enjoying different artifacts. Pakistan is a country that also earns from its agricultural sector. The recent government has been pushing for the Pakistani product to have dominance in the local market.

Foreign Direct Investment, as well as residential speculation, has been working at the advancement of the whole framework of this sector. Throughout recent years, there has been a great number of developments to promote the outcome being made from the buying of products in the marts.

The business of shopping that highlights the customer-product interaction, the autonomous mobility will be the factor that would help to boost and further push the very normal-looking day-to-day tasks into a more rewarding and relaxing experience, also opening doors for Pakistan as a country keen on the development of technology.

2.2 Existing Solutions and their drawbacks

There are few different companies that have already brought up this kind of product in the market are *Sobeys* and *Amazon*.

2.2.1 Sobeys:

Sobeys has a smart cart, working based on image processing with cameras that process and decide in seconds; the product identification is flawless as soon as the product gets into the vicinity of the cart, it gets added into the list and is displayed on the LED touchscreen attached at the front of the cart. However, they are to be manually pushed around. There is no feature of the cart being mobile autonomously.

2.2.2 Amazon:

At Amazon fresh marts, they are using high-end technology smart carts that are accurate up to 85 %, it is an extremely well and highly designed product, but again it lacks the option of following the customer, the follow-me notion is missing, so SASC is a dominant player then.

2.3 Research Papers:

Besides looking at the insights of our competitive market, we also studied a great amount of detailed information on the different technologies being used. As the world we live in has been transformed into a global village, while all the information of the world is at our fingertips [2].. In this era, autonomous mobility has become a hot topic of discussion. In order to keep up with the pace of the ever-growing technology, we have used the most advanced and sophisticated implementations in our Project (SASC) irrespective of the domain of hardware or the software.

Many of the relevant papers were reviewed in order to understand and adapt the approach that would affiliate with our understanding of the idea. Initially we looked at the approach of indoor positioning algorithm using Bluetooth Low Energy RSSI, which was implemented using the triangulation algorithm [3]. This paper helped clear our blurred perspective about using the BLE Beacon, however the triangulation method being out of our scope was going to be a tedious approach. Not limiting ourselves to the embedded domain we also turned our attention towards Digital Image Processing to enhance our understanding of the follow me idea. [4] The option of the cart following a custom tag by using image processing did seem a viable option, but it would have caused user inconvenience due to which it was dropped. Although we did not opt for many of the methods from different papers that we read, but we understood our limitations and got rid of the confusion we initially had.

For this reason, a comprehensive analysis and study on the domain of autonomous mobility, we have used the complete notion through "**Follow me robot using Bluetooth-based position estimation**" by B. V. Pradeep, E. S. Rahul, and R. R. Bhavani. Their analysis is done in this sector aligned with our approach and thought process, as the accuracy was much better, and the proposition was remarkable [5].

Chapter 3

OVERALL DESCRIPTION

3 OVERALL DESCRIPTION

The following chapter consists of the design and features of the project, which includes the beacon interaction and the RSSI readings.

3.1 Project Hardware

This project constitutes the below-mentioned hardware components:

- MPU 9250 (Gyroscope + Accelerometer + Magnetometer)
- Chassis for the cart
- HM-10 Bluetooth Module
- Lidar (TF-MINI)
- DC Gear Motors
- Raspberry Pi
- Micro-Controllers
- LCD Touchscreen
- Power Supply

3.1.1 MPU 9250:

This essential component of the project, having the magnetometer and gyroscope being integrated over a single chip, helps to provide a mechanism of orientation for the cart.

3.1.1.1 Description

The MPU-9250 is a processing unit that can be classified as (SiP) or System in Package, containing a gyroscope, accelerometer, and magnetometer responsive to the 3-axis, basically a digital compass [6].

3.1.1.2 Features

- Integrated with the BLE beacon helps to provide the IMU readings
- The processor can work all digital sensors which are non-inertial
- The high accuracy means less error in the results

3.1.1.3 Application

This little chip is the guidance system for our project; the features of the gyroscope and magnetometer help the cart to comprehend and understand where and how the cart should turn in in order to follow the path of the customer at each turn [7].

3.1.1.4 Specifications

Sr. No.	Attribute	Type/Value
1.	Type of Sensors	Accelerometer, Gyroscope, Magnetometer
2.	Power Consumption	3.7 mA
3.	Number of Channel	9
4.	Sampling Rate	50Hz

Table 1: Specification of MPU 925

3.1.1.5 Figure

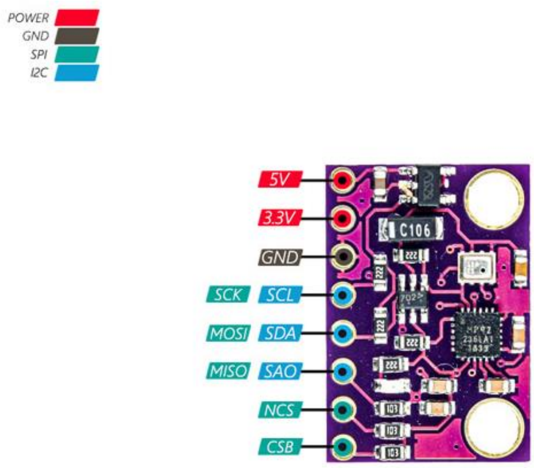

Figure 1: MPU9250

3.1.2 Cart Chassis

We shall be discussing the features of the Chassis that have been used in building this prototype.

3.1.2.1 Description

The whole prototype chassis has been created by the material called PVC foam board; having great tensile strength, you need to apply a great amount of force to break it. Having a plastic feel to it but being able to withstand the pressure, the cart is only non-vulnerable to external conditions. The material is fireproof, does not rust or get affected due to moisture like the traditional carts, which are vulnerable to weather conditions.

3.1.2.1.1 Why PVC Foam Board?

PVC foam board is also called Artificial Wood and is being used in the industry for many purposes.

It has the following benefits:

- High Tensile Strength
- Lightweight
- Waterproof
- Does not decay
- Termite proof

3.1.2.2 Features

- Lightweight
- It does not interfere with the signals because of being non-metallic in nature

3.1.2.3 Specifications

The whole cart was created and modified using AUTOCAD, all the dimensions have been mathematically adjusted for the structure to appear as a standard cart, yet a modern touch has been added to make it stand out. Touchscreen LCD has been added at the front for the customer to keep track of his/her items bought.

3.1.2.3.1 Technical Specifications

Sr. No.	Properties	Value	Unit (SI)
1	Density	80	Kg / m^3
2	Tensile Strength	2	N / mm^2
3	Compressive Strength	1.45	N / mm^2
4	Shear Strength	1.2	N / mm^2
5	Tensile Modulus	66	N / mm^2

Table 2: Specifications of PVC Foam Board

3.1.2.4 Applications

The cart has the following applications:

- To fully manipulate the actions of a shopping cart
- Display the items on the touch screen LCD mounted at the front
- Keep following the customer aisle to aisle without need for human effort
- Maintain and function on the set threshold boundaries

3.1.2.5 Figure

Nesting Distance	W1	W2	W3	L1	L2	H1	H2	H3	H4	Weight in lbs.
8 3/4	18	20	15	20 3/4	28 1/4	36	32	12Â 7/16	15 5/8	38

Figure 2: AUTOCAD created Chassis design

3.1.3 HM 10 module:

We are explaining the useful features of the component in the following units, highlighting how important was the Bluetooth module to keep the communication alive.

3.1.3.1 Description

The Chip-based component acts like a transceiver to help connect the Beacon to help gain the readings and operate on them to be able to comprehend the required action that needs to be taken. The whole guidance and turning mechanism lie on the readings from the Bluetooth module. The communication is serial.

3.1.3.2 Features

- To allow serial communication of the readings successfully
- Low energy consumption
- Works at a frequency of 2.4GHZ
- Contains 12 pins of general-purpose Input/Output

3.1.3.3 Specifications

Sr. No.	Property Name	Property Value
1	Voltage supply	3.6 V - 6 V
2	RF power: -	23dbm, -6dbm, 0dbm, 6dbm
3	Default baud rate	9600
4	Maximum Current	50mA
5	Frequency	2.4GHz
6	Default Pin	000000

Table 3:Specification of HM-10

3.1.3.4 Figure

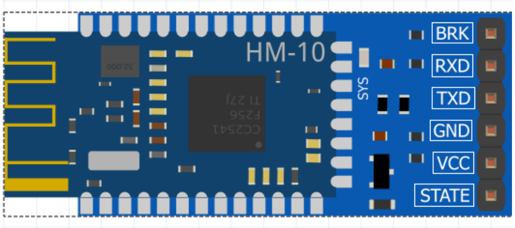

Figure 3:HM-10 Module

3.1.4 LIDAR (TF-MINI):

The component responsible for obstacle detection provides seamless movement.

3.1.4.1 Description

The obstacle detection system, using light as a method to detect whether there is a presence of an object in part; this saves the cart from bumping into hurdles that would put the functionality of the cart into jeopardy. The optical mechanism not only displays Distance but helps to analyze the trajectory of the path the cart must travel.

3.1.4.2 Features

- High accuracy of distance measurement till 12 meters
- Works at a low voltage of 5V
- Uses UART of 115200 baud rates

3.1.4.3 Specifications

Sr. No.	Attribute	Value
1.	Operating Range	0.3m-12m
2.	Max operating range at 10% ref	5m
3.	Average power consumption	0.6 W
4.	Operating Voltage	4.5-6V
5.	Acceptable Angle	2.3°
6.	Frequency	100Hz
7.	Accuracy	1% (less then 6m) 2%(6m-12m)
8.	Distance Detection unit	Centimeter (cm)
9.	Wavelength	850nm
10.	Size	42mm*15mm*16mm
11.	Light Sensitivity	70,000Lux
12.	Weight	4.7 g
13.	Communication interface	UART 115200
14.	Serial port TTL voltage level	3.3V
15.	Electromagnetic Compatibility	EN 55032 Class B

Table 4:Specifications for TF-MINI

3.1.4.4 Applications

- used in automobiles for obstacle avoidance
- Sensor circuits

3.1.4.5 Figure

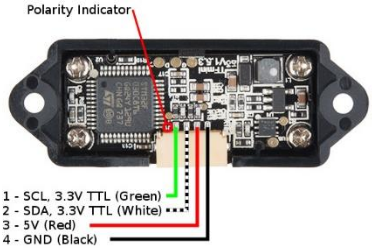

Figure 4:Pinout TF-MINI

3.1.5 Gear Motors (AMETEK Pittman):

The following section discusses the gear motors we have used for motion

3.1.5.1 Description

The gear motors provide the function of moving the cart, and the gear motors were a great option having the specifications that perfectly fit it to support the whole notion of autonomous mobility. 2 gear motors have been used on the project, at the rear side and one-two freewheels at the front, they turn into the directions as commanded by the rear motors.

3.1.5.2 Features

- 12/24 VDC
- 127 rpm (at 0 loads)
- Maximum brush life is ensured because of diamond-turned commutators
- Standard brushes made up of copper graphite

3.1.5.3 Specifications

Product Attribute	**Attribute Value**
Bearing Type	Ball
Current Rating	5.2 A
Gear Type	Wide Face
Input Power	13 W
Nominal Voltage	12/24 VDC
Primary Type	Motors
Series	GM923 Series
Shaft Length	3.676 In
Speed	123 RPM
Torque	200 Oz.-in
Type	Brush Commutated DC Gear Motor
Weight	16.6 Oz

Table 5:Specifications of the Gear Motors

3.1.5.4 Applications

- Lab automation
- Aerospace systems
- Communication equipment

3.1.5.5 Figure


Figure 5:Pictures of the gear motors in a different orientation

3.1.6 Raspberry Pi:

The most integral component is responsible for the processing of the data upon which the cart will be making decisions regarding its maneuver.

3.1.6.1 Description

This is a small Single-board Computer that is capable of handling a large amount of data at a very High Bitrate. The Raspberry Pi 4 (2GB) is the Brain for the cart. Its purpose is to Sample RSSI, Process the IMU Readings, Interface the GUI and Communicate with the Bar code Scanner [8].

3.1.6.2 Features

- HDMI ports up to 4K resolution
- 40 GPIO pins
- Integrated Bluetooth 5.1 (BLE)
- Dual-Band (2.4GHz/5GHz) Wireless LAN
- Supports USB 3.0

3.1.6.3 Specifications

Sr. No.	Property Name	Property Value
1	Operating Voltage	5V
2	Working Current	3A
3	Processor	Broadcom BCM2711, quad-core Cortex-A72 (ARM v8) 64-bit SoC @ 1.5GHz
4	Wireless Criteria	802.11 b/g/n
5	idle power consumption	540mA (2.7W)
6	Dimensions	85.6mm × 56.5mm
7	Bluetooth	5.0 BLE
8	RAM	2-GB

Table 6:Specifications of Raspberry Pi 4

3.1.6.4 Applications

- ➢ High-Speed Processing
- ➢ Act as a Portable Computer System

3.1.6.5 Figure

Figure 6: Raspberry Pi 4

3.1.7 Micro-Controller's:

The Micro-Controllers are part of the components with high processing abilities.

3.1.7.1 Description

Two microcontrollers were used in the project.

- Atmel SAM3X8E ARM Cortex-M3
- ATmega328

Atmel SAM3X8E ARM Cortex-M3:

This Microcontroller is also Known as Arduino DUE. This is a Dual-core High-Speed Micro-controller that can handle Baud rates Much higher than other members of the Arduino Family.

ATmega328(Pro-Mini):

This Microcontroller is used in many Boards, of which we used Pro mini Because of its small size and low power consumption [9].

3.1.7.2 Features

Atmel SAM3X8E ARM Cortex-M3:

- Up to 84 MHz Clock Frequency
- 4 Serial Interfaces
- 54 digital I/O pins, 12 analog input pins, 2 DAC, and 2 CAN
- Nested Vector Interrupt Controller

ATmega328(Pro-Mini):

- 14 digital input/output pins (6 PWM), six analog input pins
- Up to 16 MHz Clock (8MHz for our case)
- Can Operate at 3.3V input

3.1.7.3 Specifications

Sr. No.	Property Name	Property Value
I	Operating Voltage	7-12V
2	Working Current	130mA
3	Processor	Atmel SAM3X8E ARM Cortex-M3
4	embedded Flash Memory	256 to 512 Kbytes
5	idle power consumption	80mA
6	SRAM	32 to 100 Kbytes
7	ROM	−16 Kbytes
8	RAM buffer	4 Kbytes

Table 7: specifications of Arduino DUE

Sr. No.	Property Name	Property Value
I	Operating Voltage	3.3-12V
2	Working Current	200mA
3	Processor	Atmega328(8MHz)
4	Flash Memory	32Kbytes
5	SRAM	2Kbytes
6	Dimensions	33mm × 18mm
7	UART	1 port

Table 8: specifications of Arduino Pro mini

3.1.7.4 Applications

Atmel SAM3X8E ARM Cortex-M3:

- Complex projects
- High-speed Processing

ATmega328(Pro-Mini):

- Small modules
- Semi-Permanent Installation

3.1.7.5 Figure

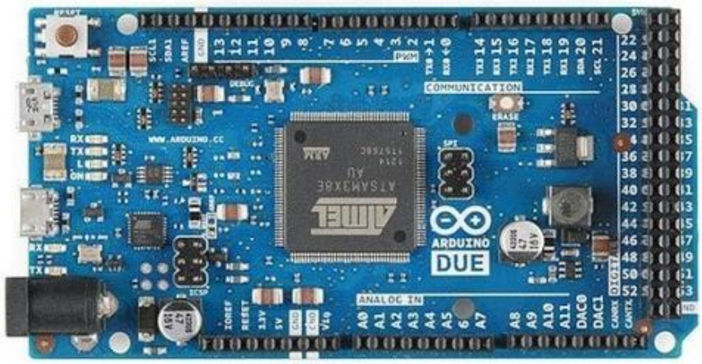

Figure 7: Arduino Due

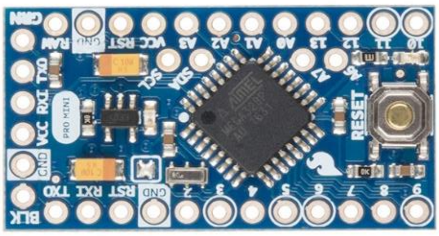

Figure 8: Arduino Pro Mini

3.1.8 LCD Touchscreen:

We shall be looking at the use and specifications of LCD touchscreen integrated as hardware in the project.

3.1.8.1 Description

A 5-inch LCD touchscreen has been used to Display the Graphical User interface that the user will be interacting with. The LCD will be used to view the Shopping List, the Price of the Scanned Product, The location of the item, and the map of the Store [10].

3.1.8.2 Features

- 800x480 high hardware resolution
- Resistive touch control
- Backlight can be turned off to lower power consumption

3.1.8.3 Specifications

Sr. No.	Property Name	Property Value
I	Operating Voltage	5V
2	Working Current	150mA
3	Resolution	800x480
4	Touch Type	Resistive
5	Weight	120g
6	Dimensions	133mm x 76mm x 7mm

Table 9:Specifications of the LCD touchscreen

3.1.8.4 Applications

- Lab automation
- Aerospace systems
- Communication equipment

3.1.8.5 Figure

Figure 9:LCD touchscreen

3.1.9 Power Supply:

The section covers the area of the Power supply being the final part of the hardware section for this project. The Section is divided into two parts. We have different power supplies for the Beacon and the Raspberry Pi.

3.1.9.1 For Beacon

To charge the Beacon, we have used a lithium polymer battery which would provide a Voltage of 3.7 V to which would be enough to power up the Arduino pro mini, MPU-9250, and HM-10 Bluetooth module [11].

3.1.9.2 For Raspberry Pi 4

To sustain the whole cart for effective operation, we are using a dry battery of 12/24V. Powering the gear motor, Lidar, and all other components integrated on the cart.

3.2 Project Software

SASC was implemented on the following software platforms:

3.2.1 Thonny IDE:

The environment for running codes using Raspberry Pi has been discussed below:

3.2.1.1 Description

The whole coding was done using Raspbian OS. It was very easy to make the logic and to refine the codes and upload them to the board. The environment was Thonny.

3.2.1.2 Features

Thonny provides an environment that acts just as if it were a Python IDE and helps to compile the codes, being simple and easy to use.

3.2.1.3 Application

Thonny IDE, in the Project SASC, was used to do the following tasks [12]:

- Writing codes to acquire IMU readings
- Compilation and understanding of RSSI values
- Keeping threshold values to maintain Beacon and Pi communication

3.2.1.4 Version

Thonny IDE's latest version of 3.3.10 was used in the Project

3.2.2 Arduino IDE:

The environment for running Arduino codes has been mentioned below:

3.2.2.1 Description

The Arduino IDE being open source in nature eases the ability to make codes and uploading them without any issues. Java being the environment [13].

3.2.2.2 Features

It is running on code compiled by the machine from C++ or C language having a compiler for the instruction set for the Arduino.

3.2.2.3 Application

The following were implemented on SASC:

- Manipulating oriental axis of the Beacon
- Setting boundaries about the directions from the Beacon
- Refinement of the IMU values

3.2.2.4 Version

Version 1.8.12 of Arduino was used in this Project

3.2.3 Auto-CAD:

The Chassis of the Cart was designed and modified using Auto-CAD to ensure accurate precision in the dimensions.

3.2.3.1 Description

It is a computer-aided design and drafting software application. Developed by Autodesk, with which the user can design complex drawings in 3-Dimensions.

3.2.3.2 Features

- 3D Modeling and Visualization.
- Photorealistic Rendering.
- Solid, Surface, and Mesh Modeling.

3.2.3.3 Application

The following were implemented on SASC:

- Design of the initial drawing of the cart.
- Visualization of our cart design before construction

Chapter 4

DESIGN AND DEVELOPMENT

4 DESIGN AND DEVELOPMENT

The Section contains details about the phase where the whole project was designed and integrated together, and all components started performing the necessary tasks.

4.1 Handheld Beacon

The Handheld beacon plays a very vital role in providing the required information for the cart to comprehend.

4.1.1 Overview:

The manually assembled Beacon contains the MPU-9250, the lithium battery providing and Direct Current of 3.7V and 4600 mAh battery life; along with it, we have the Arduino pro-mini. The serial communication takes place between the Pro Mini and the HM-10 BLE Module.

4.1.2 Attaching the MPU-9250 Module:

This Module is used to acquire the Inertial Measurement Unit (IMU) Readings, which are Further used to ascertain the direction of motion.

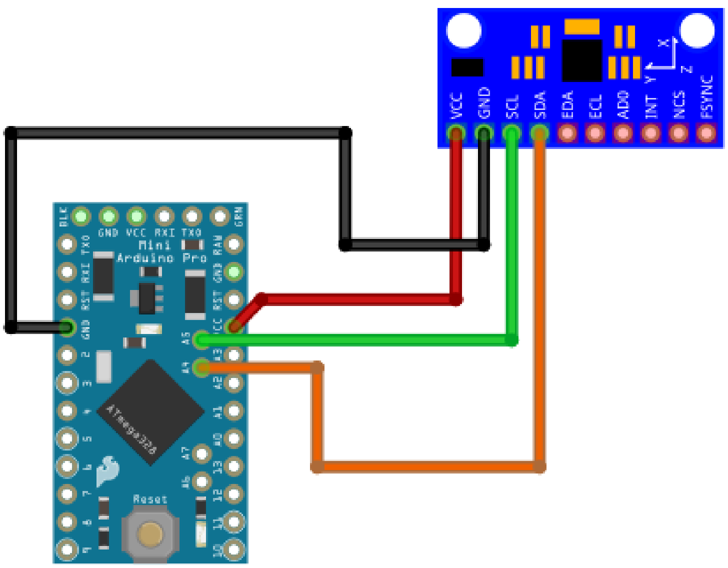

Figure 10: MPU-9250 connected with Arduino Pro-Mini

4.1.3 Integration of Bluetooth Module:

All the data that is being received by the MPU-9250 is incomplete until and unless the Bluetooth module is made a part of it. The values start to make sense later.

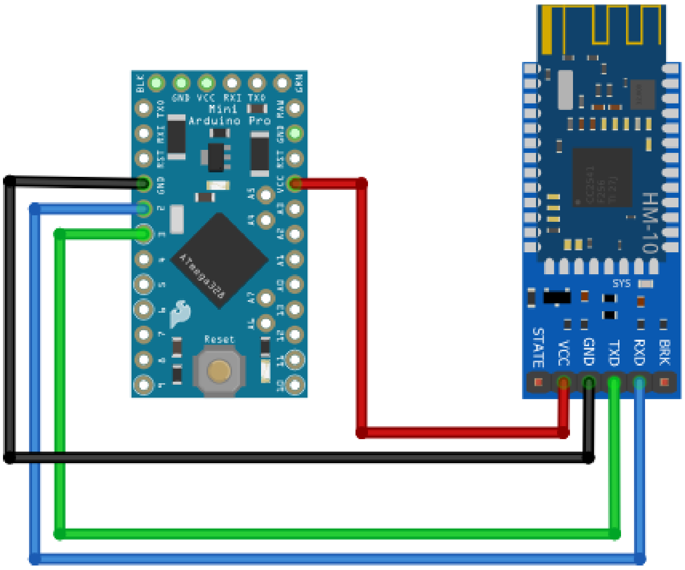

Figure 11: HM-10 connected with Arduino Pro Mini

4.1.4 Circuit Design of the Transmitter module:

For the integration of all these together, the components were soldered on the body of the Battery. And a charging module was used to make it a rechargeable beacon for the cart. A switch was added to the Beacon for turning it on/off [14].

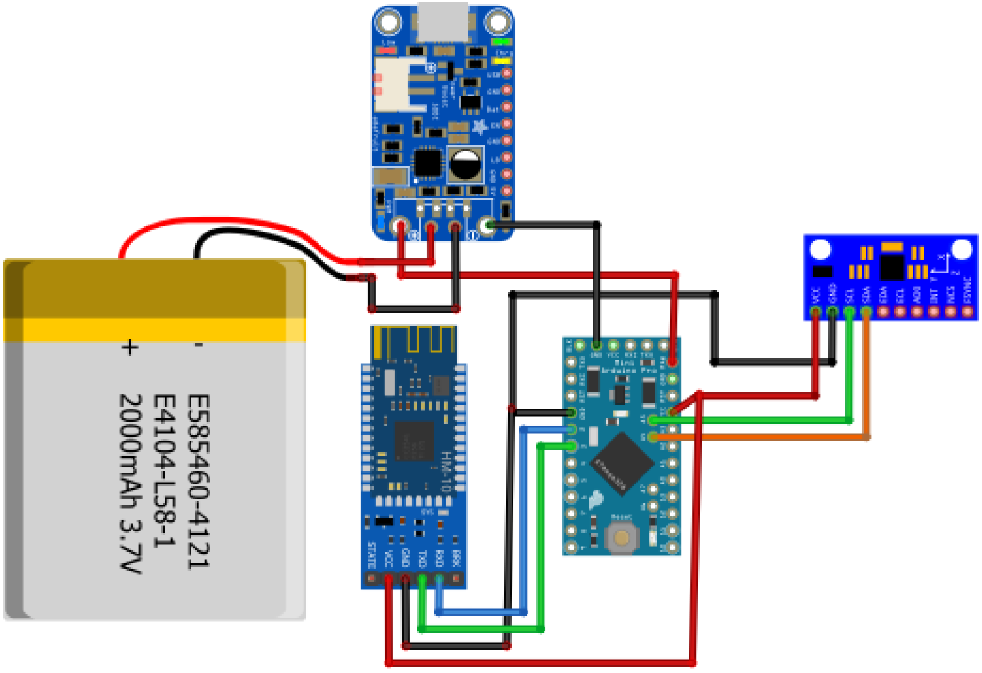

Figure 12: Final Circuit of the Beacon

4.2 Cart integration

The Chapter focuses on the testing and compilation stage of our project.

4.2.1 Overview:

After receiving the readings over the Bluetooth from HM-10, the readings are then combined with the results from LIDAR, upon which the RSSI and IMU readings help decide how to maneuver the cart. The motor drive (H-bridge) is connected to the Arduino due.

4.2.2 Integration of the Lidar

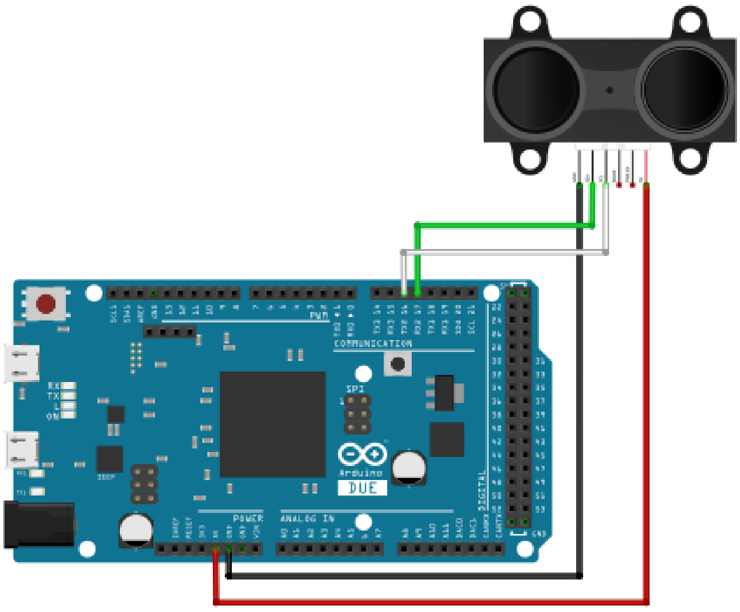

Figure 13: Arduino Due connected with TF-Mini LiDAR

4.2.3 Mounting of the Lidar on the Servo

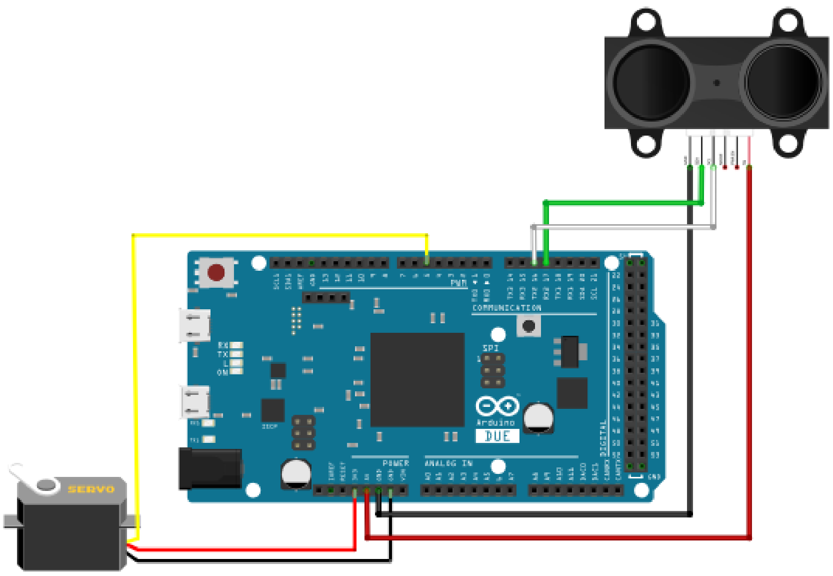

Figure 14: Arduino Due connected with TF-Mini LiDAR and Servo

4.2.4 Integrating the Raspberry pi

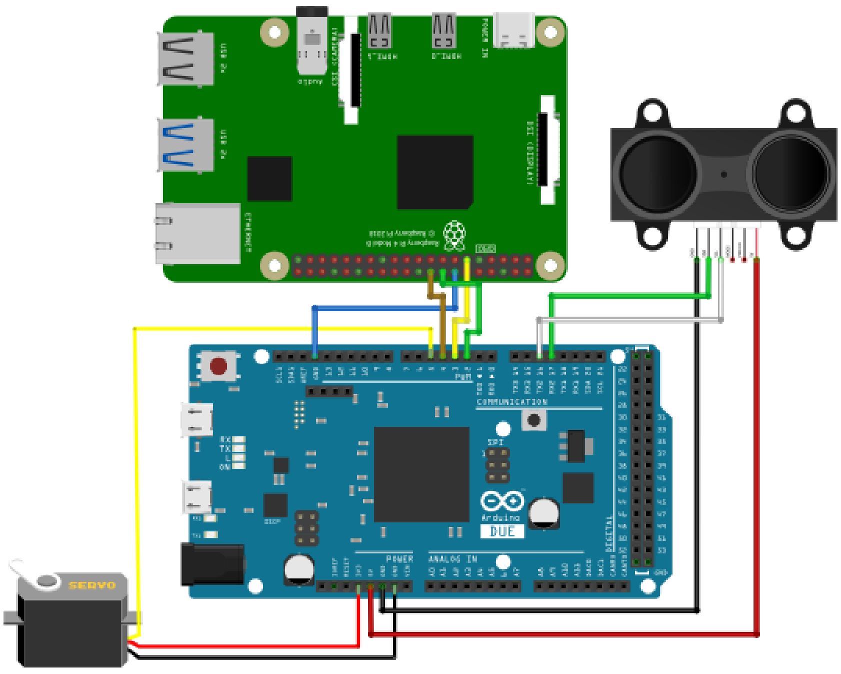

Figure 15: Integration of Raspberry Pi and Arduino

4.2.5 Attaching the Motor Driver

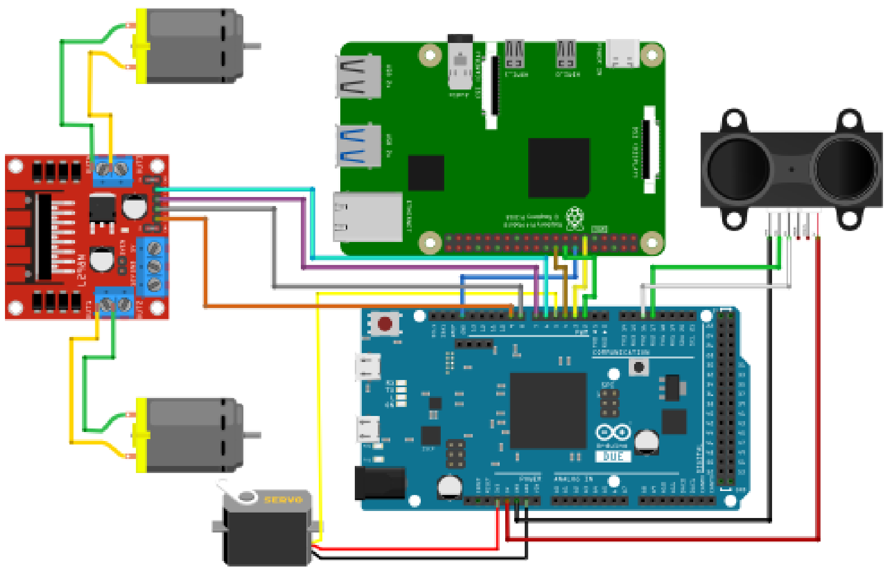

Figure 16: H-Bridge Motor Driver connected with Arduino

4.3 Testing of the IMU readings:

An illustrated analysis of the IMU readings being tested over the HM-10

- Receiving values from the MPU-9250
- The values are in ASCII
- The values are scrambled and inaccurate because they were not refined
- This testing was done over an android application confirming the MPU-9250 Module to be in a good shape

The parameters used are gyroscope, magnetometer, and accelerometer. We are observing the Serially Received values and the connection with MLT-BT05 that is providing us with a scrambled dataset of values. At this stage, the receiving of the values was given more priority rather than separately working on each of the parameters and setting the codes accordingly.

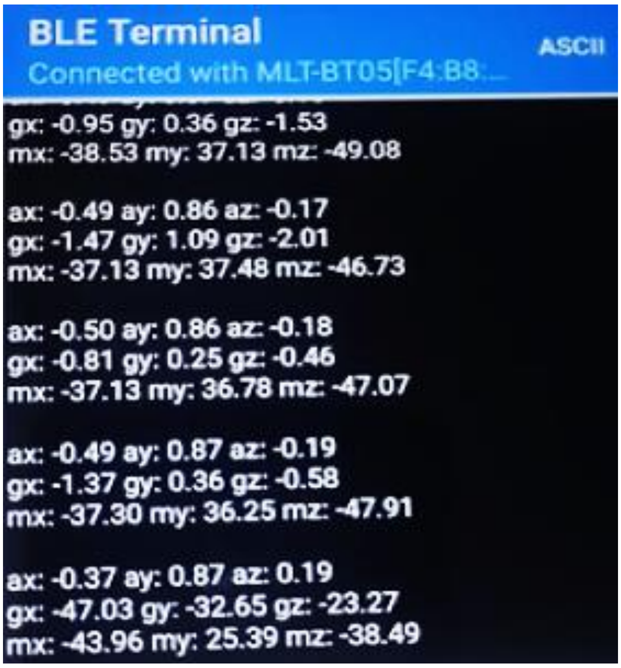

Figure 17:Getting visual display of readings of MPU-9250 over Bluetooth

4.4 Preliminary Testing of the Cart

After being assembled with geared motors and crafted using the PVC foam board, the cart was tested using a remote-control module to check if the motors were aligned properly and the motor driver responded effectively. At this stage, autonomous mobility has not been installed into the cart, as this was a premature test of the architectural dimension.

The whole prototype can carry up to 15kgs with no compromise in speed

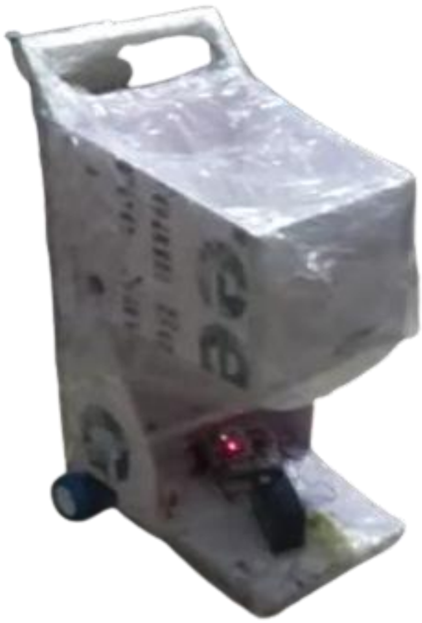

Figure 18: SASC chassis and initial testing completed

Following are the pictures of the handheld Beacon after successful assembly and transmitting the necessary values for the cart to function upon.

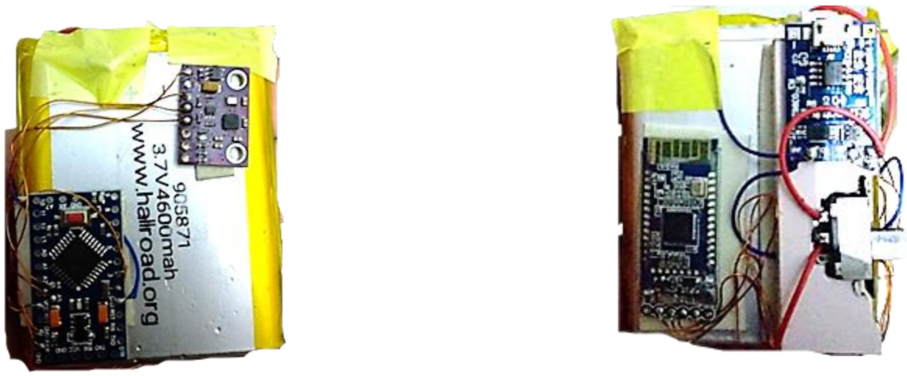

Figure 19: MPU-9250 / Arduino Pro mini (Left) and HM-10 / Lipo Charging Module (Right)

4.5 Grabbing the RSSI values

We get the Distance from the RSSI values, which indicate the distance between the cart and the Beacon. This helps to ensure and send a reflex to the cart that it must maintain a certain threshold from the customer.

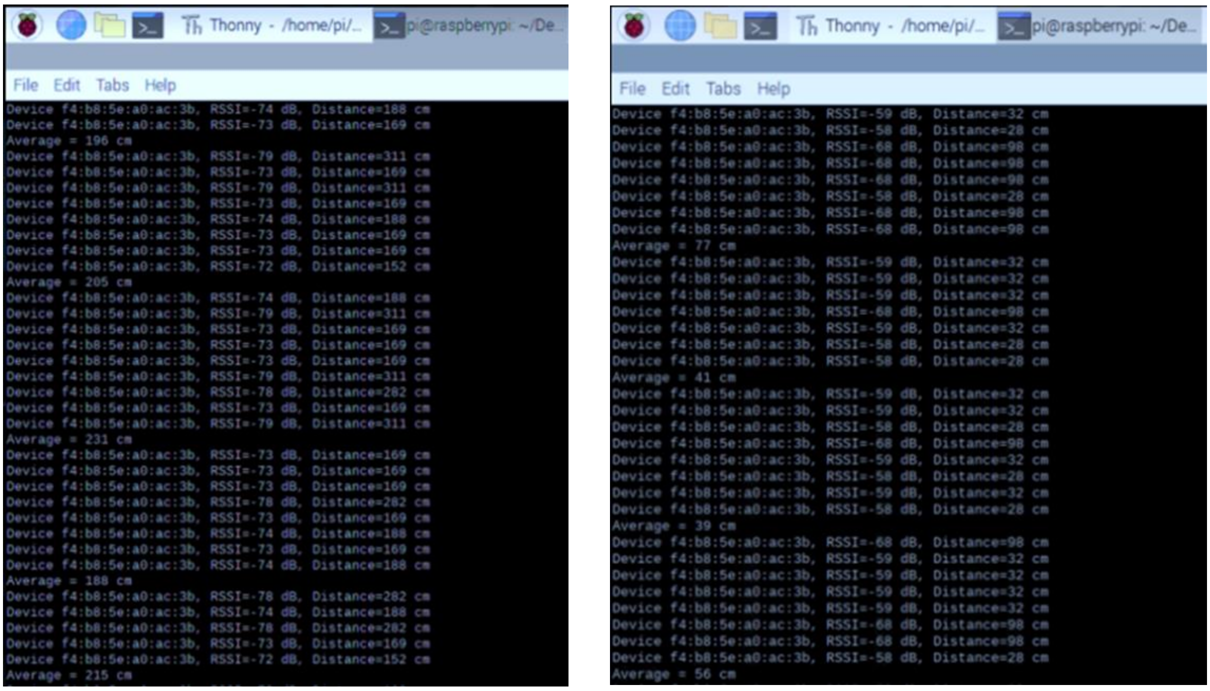

Figure 20: Beacon closer to Raspberry Pi (Left), Beacon away from Raspberry Pi (Right)

For getting a better analysis of the RSSI readings, we are also taking the average of about 7-8 readings, and after every 1 second, we are taking the readings and refreshing and updating the results to keep checking if the Distance has changed or not, to keep the cart stationary or in motion.

Chapter 5

PROJECT INTEGRATION

5 PROJECT INTEGRATION

This Chapter includes the understanding and working of the project.

5.1 Fortification of Beacon Orientation

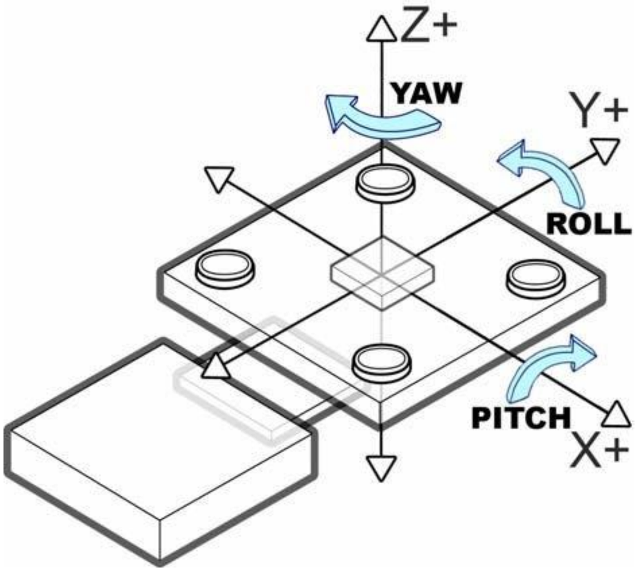

Figure 21: Representation of the Axial Dimensions

For the cart to follow the customer successfully, the mechanism of positioning must be precise and accurate so the cart can analyze and locate the presence of the Beacon hence properly following the customer and turning accurately at every point of curvature [15]. The positioning here is based upon the 3 Dimension, being YAW, which represents the Z-axis. ROLL that depicts the Y-axis and finally PITCH that works on the x-axis.

5.2 Distance calculation using RSSI

```
while True:
    while p.waitForNotifications(2):
        devices = scanner.scan(0.1)
        for ii in devices:
            if ii.addr == 'ec:24:b8:31:c3:95':
                ratio = (ii.rssi)*1.0/(-37)
                avg_distance = (0.89976) * (pow(ratio,7.7095)) + 0.111
                print("\nRSSI_Distance=%d cm" % (avg_distance))
```

Figure 22: Calculation of Distance Using RSSI

The Raspberry Pi is calculating the RSSI values coming from the Beacon to find out the Distance it has between the Beacon and the cart. We are calculating the average of the values to comprehend a much better figure. After the average values are found, they are printed, and then the loop starts all over again.

5.3 Calculation of the IMU values

```
def handleNotification(self, cHandle, data):
    global avg_distance
    global yaw
    msg = data.decode("utf-8")
    pry = ["a","a","a"]
    j = 0
    temp_str = ""
    for ch in msg:
        if ch == 'x':
            pry[j] = temp_str[1:]
            temp_str = ""
            j = j + 1
        temp_str += ch
    if pry == ["a","a","a"]:
        return
    pry = list(map(float, pry))

    diff = pry[2] - yaw
    print ("\nYaw_Difference= " + str(diff))
    if avg_distance < 200:
        print "\nStop!"
        Left.off()
        Right.off()
        Forward.off()
    elif diff >= 0.2:
        print "\nLeft Turn"
        Left.on()
        Right.off()
        Forward.off()
    elif diff <= -0.2:
        print "\nRight Turn"
        Left.off()
        Right.on()
        Forward.off()
    else:
        print "\nForward"
        Forward.on()
        Right.off()
        Left.off()

    yaw = pry[2]
```

Figure 23: Code for Calculation of Pitch, Roll, and Yaw

The Bluetooth module, HM-10, has the options of Read, Write, and Notification. We have used the notification function that is called every time a characteristics changes; its string is read and broken down into YAW, PITCH, and ROLL [16].

We are calculating the difference of the current and the previous values of the YAW and storing it in the variable called *diff*. Putting conditions on the difference of YAW values helps us to decide the turning mechanism. After extensive experimentation, we found the threshold to be 0.2, giving us desired result.

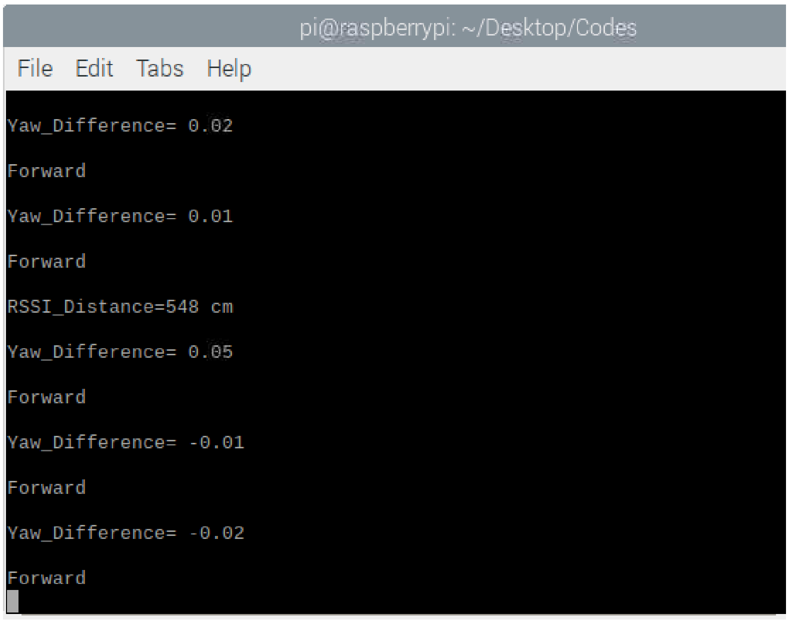

Figure 24: Output of the RSSI and IMU Calculations

The output we are getting is based upon the Distance we are getting from the RSSI values, along with the IMU readings that give us the directions, and from these, we are getting the decisions of forwarding, Right or Left [17].

5.4 Beacon Refinement

```
fabo_9axis.readAccelXYZ(&ax,&ay,&az);
fabo_9axis.readGyroXYZ(&gx,&gy,&gz);
fabo_9axis.readMagnetXYZ(&mx,&my,&mz);
'  fabo_9axis.readTemperature(&temp);

pitch = atan2 (ay ,( sqrt ((ax * ax) + (az * az))));
roll = atan2(-ax ,( sqrt((ay * ay) + (az * az))));

// yaw from mag

float Yh = (my * cos(roll)) - (mz * sin(roll));
float Xh = (mx * cos(pitch))+(my * sin(roll)*sin(pitch)) + (mz * cos(roll) * sin(pitch));

yaw =  atan2(Yh, Xh);

msg += "a" + String(pitch, 2) + "x" + String(roll, 2) + "x" + String(yaw, 2) + "x";

Serial.println(msg);
HM10.print(msg);
```

Figure 25:Code for Atmel 328p (Arduino Pro Mini)

Arduino Pro Mini is taking the values from MPU-9250 [18], which are of the magnetometer, gyroscope, and accelerometer. We get nine values from these three parameters. Next, we calculate the PITCH and ROLL to get the YAW. Finally, these values are serially sent to the HM-10 Bluetooth module.

A protective casing was made for the Beacon to minimize shock and damage.

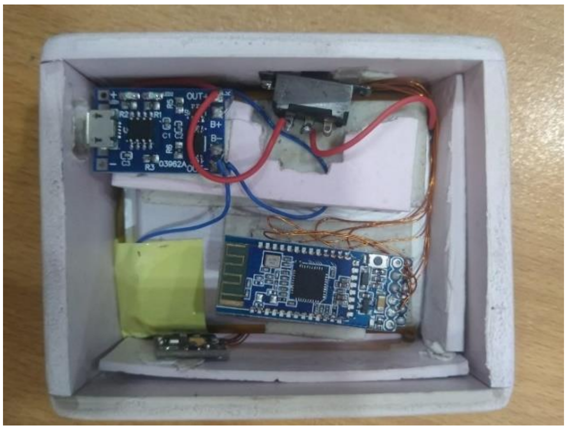

Figure 26: Final Beacon images with Protective casing

5.5 Lidar Integration on Servo

```
void getTFminiData(int* distance, int* strength) {
  static char i = 0;
  char j = 0;
  int checksum = 0;
  static int rx[9];
  if(Serial2.available())
  {
    // Serial.println( "tfmini serial available" );
    rx[i] = Serial2.read();
    if(rx[0] != 0x59) {
      i = 0;
    } else if(i == 1 && rx[1] != 0x59) {
      i = 0;
    } else if(i == 8) {
      for(j = 0; j < 8; j++) {
        checksum += rx[j];
      }
      if(rx[8] == (checksum % 256)) {
        *distance = rx[2] + rx[3] * 256;
        *strength = rx[4] + rx[5] * 256;
      }
      i = 0;
    } else
    {
      i++;
    }
  }
}
```

Figure 27:Function for calculating Distance using the Lidar

The Servo is rotated from 0 to 180° degrees and vice versa. This allows the TF-Mini [19] to detect obstacles with a wider field of view. Arduino Due is processing the data from the Lidar and making decisions for obstacle avoidance accordingly [20].

5.6 Arduino Due ARM Cortex-M3

```
if (distance <=35){
  if (i < 60){
    Serial.print("Right Obstacle");
    digitalWrite(6, LOW);
    digitalWrite(7, HIGH);
    digitalWrite(8, HIGH);
    digitalWrite(9, LOW);
    }
  else if (i > 120){
    Serial.print("Left Obstacle");
    digitalWrite(6, HIGH);
    digitalWrite(7, LOW);
    digitalWrite(8, LOW);
    digitalWrite(9, HIGH);
    }
  else{
    digitalWrite(6, LOW);
    digitalWrite(7, LOW);
    digitalWrite(8, LOW);
    digitalWrite(9, LOW);
    Serial.print("Stop Front Obstacle");
    }
  while(distance <=35){
    getTFminiData(&distance, &strength);
    }

}
```

```
else if(F){
  digitalWrite(6, HIGH);
  digitalWrite(7, LOW);
  digitalWrite(8, HIGH);
  digitalWrite(9, LOW);
  Serial.print("\nForward\n");
}
else if(R){
  digitalWrite(6, HIGH);
  digitalWrite(7, LOW);
  digitalWrite(8, LOW);
  digitalWrite(9, HIGH);
  Serial.print("\nRight\n");
}
else if(L){
  digitalWrite(6, LOW);
  digitalWrite(7, HIGH);
  digitalWrite(8, HIGH);
  digitalWrite(9, LOW);
  Serial.print("\nLeft\n");
}
else{
  digitalWrite(6, LOW);
  digitalWrite(7, LOW);
  digitalWrite(8, LOW);
  digitalWrite(9, LOW);
  Serial.print("Stop Front Obstacle");
  }
```

Figure 28:Code for motor driver and obstacle avoidance from Servo and lidar data

The Arduino Due is responsible for the movement of the cart. It takes data from the Raspberry Pi and Lidar. The movement is decided to depend upon the angle at which the obstacle is perceived. As well as the direction it gets from the Raspberry Pi [21].

5.7 The Barcode Scanner

A 1-Dimension barcode scanner was used for scanning the products and adding them to the shopping list. The barcode scanner is connected to the Raspberry pi using a Serial Interface and can scan with an accuracy of 99% [22].

5.7.1 Figure

Figure 29:Barcode scanner

5.8 The Graphical User Interface

The Chapter discusses the Graphical User Interface of the touchscreen LCD integrated into the cart and attached to the barcode scanner.

5.8.1 The Code

```python
from tkinter import *
import tkinter.filedialog
import csv

class App(Tk):
    def __init__(self):
        Tk.__init__(self)

        self.title("SASC")
        self.geometry("800x480+0+0")
        self.headerFont = ("Helvetica", "10")
        self.bind('<Return>', self.getSearchResults)
        self.addComponents()

        # Much of the information will be stored in ar
        # Each column in our CSV file (item name, pric
        # Index position 2 in any of our arrays (once
        # position 2 in any other of its arrays
        # For example 2% Milk costs $4.78 and is in se
            # if 2% Milk is in index position 3 in the
            # arrays (price, section, shelf) will have
        self.searchResultsItemNames = []
        self.searchResultsItemPrices = []
        self.searchResultsItemSections = []
        self.searchResultsItemShelfs = []

        self.nameReferences = []
```

Figure 30:Code for the Graphical User Interface

We are using the Tkinter library for the GUI, which will help to give the customer a clear and simple visualization about his products, which would ease up his shopping experience [23].

5.8.2 The Interface

The following are the screenshots attached from the LCD, which display the outcome every time a barcode of a certain product is scanned [24].

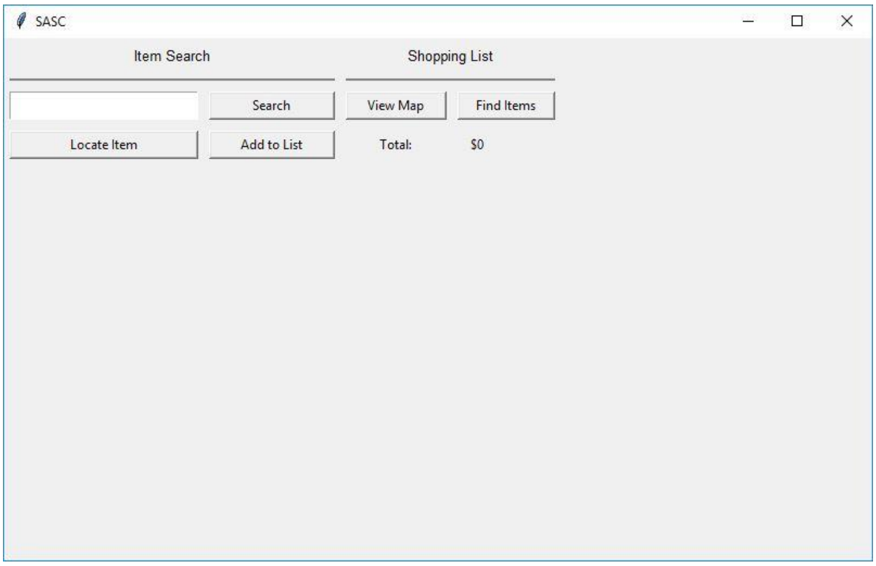

Figure 31:Output Screen for the GUI

The first interaction of the customer is how the screen appears with options that assist the customer for further information.

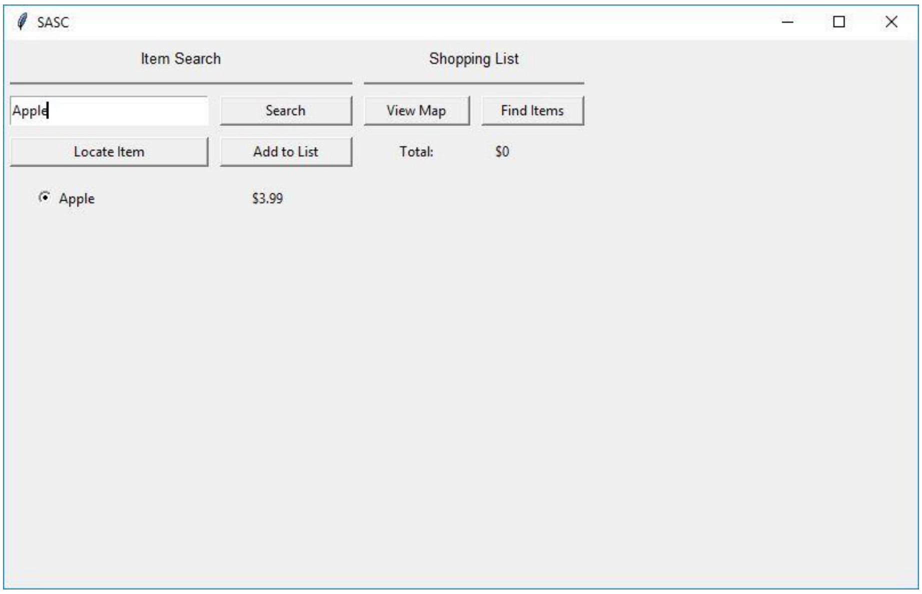

Figure 32:Main Screen of the GUI

The display after the first product has been scanned from the handheld barcode scanner. The product being an Apple has been read and displayed in the cart, with its price displayed.

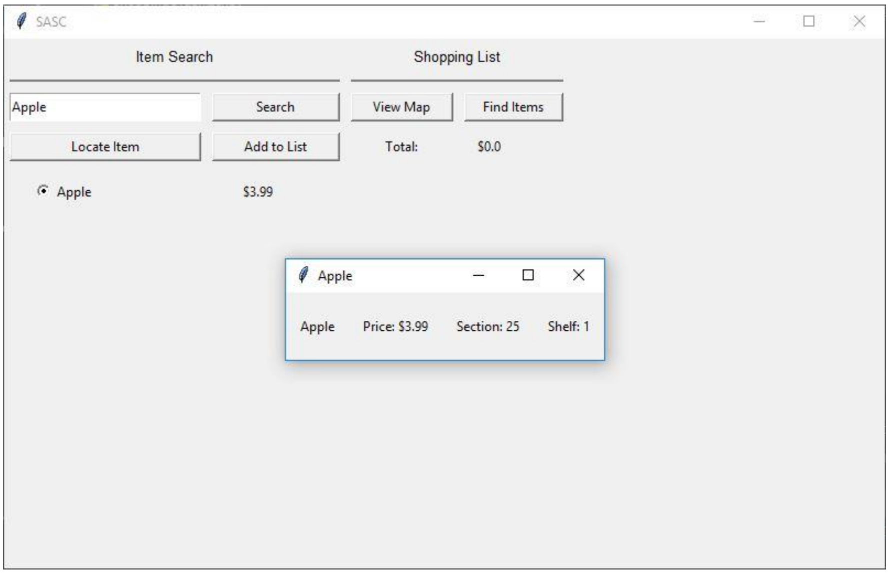

Figure 33:Location of an item in the Store

Once the option of *Locate item* is selected, the following information is displayed on the screen giving the customer the section in which the product can be found and the shelf number in the aisle.

Figure 34: Map of the Store for reference of position of the aisle

Every time the option of *View Map* is selected, we get to see the map of the store displaying necessary information to understand the aisle layout of the store.

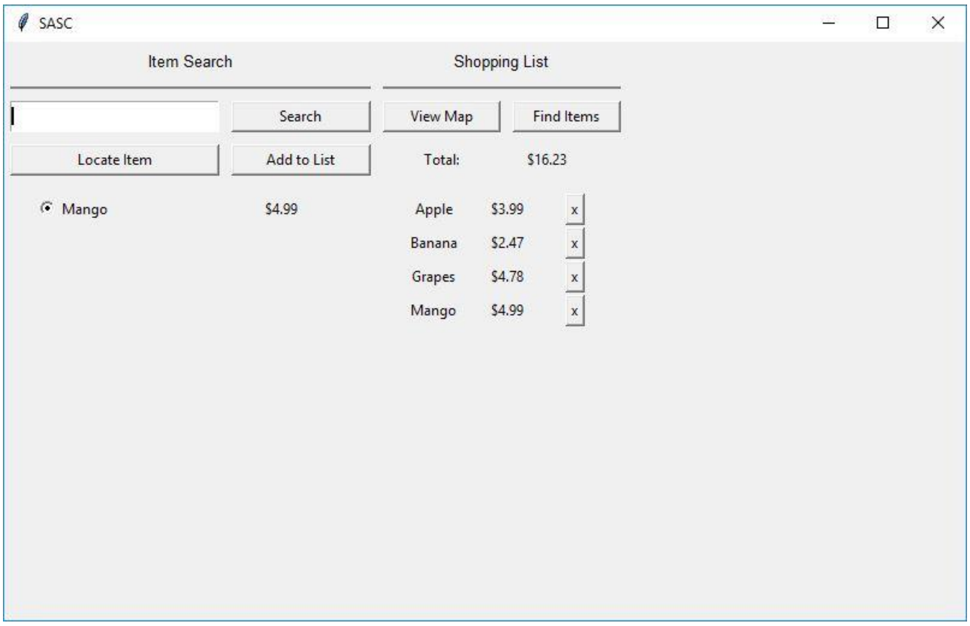

Figure 35:Products added to the Shopping Cart

As the products are scanned and added to the list, the status of the list keeps updating accordingly, and you can view the total cost being displayed along with the items.

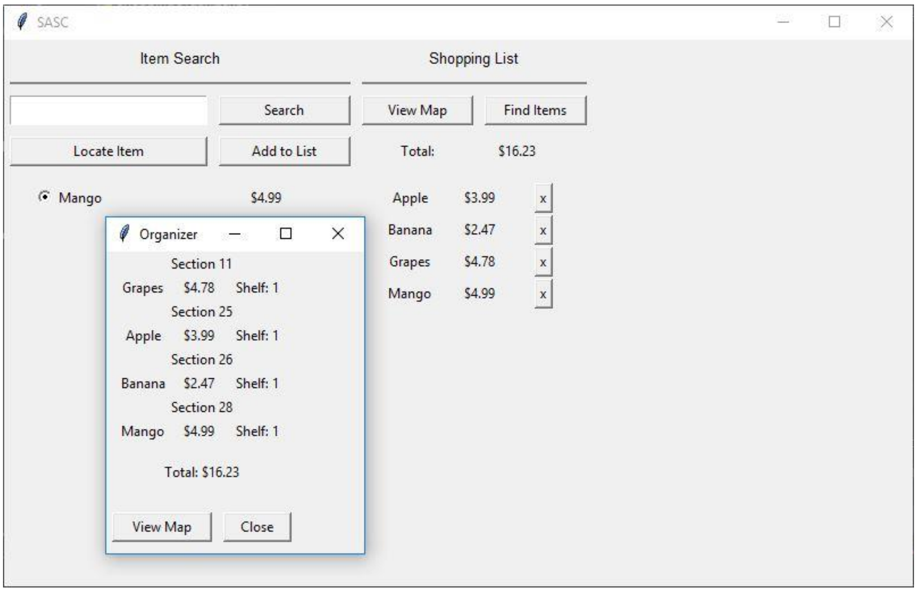

Figure 36:Displaying the List and location of your Products

The organizer view helps to provide the list and locations of all the items, along with the section they are present in the store.

Chapter 6

ANALYSIS AND EVALUTATION

6 ANALYSIS AND EVALUATION

We are assessing the project in this Chapter.

6.1 Bock Diagram

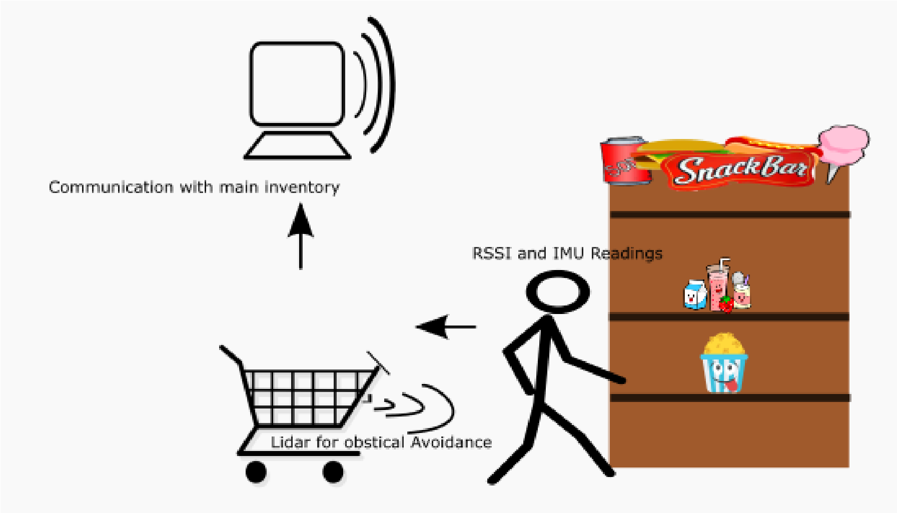

Figure 37:Block Diagram of Communication between cart, user, and store

6.2 Achievement of Objectives

After completion of the project and successful implementation, the objectives achieved are listed as follows:

- Successful ignition of the cart, keeping all the modules synchronized
- Transmission and the Receiving of the values from Beacon to cart
- LIDAR responding in accordance with the parameters set
- Barcode scanner working perfectly with the hardware
- GUI is simple yet sophisticated enough to perform as per requirement

6.3 Some Improvements Needed

Currently, the following points need to be improved upon:

- A sampling of the RSSI, For a better approximation of Distance
- Speed of the Cart when following the User
- Better Design for turning and improved stability

Chapter 7

FUTURE WORK

7 FUTURE WORK

Future possibilities and advancements in the prototype are covered in this Chapter.

7.1 Enhancement of Scope

Whilst the laid scope of our projects has completed all its objectives set earlier. It does, however, necessitate room for further refinement as does in any of the ideas in the innovative domain [25].

7.1.1 Hybrid Model:

SASC can be deployed a hybrid model as an upgrade, rather than using a simple lithium battery that requires charging after some time. We could install a hybrid battery module that would charge the battery every time it was in motion. This would improve the performance with long-lasting performance [26].

7.1.2 Deployment in the Aviation Sector:

With little revisions on the current model, we could also use the same cart at the airports, where it gets lethargic for the flyers to carry around their language to the designated terminals. The modified version could really bring a big revolution in the aviation sector through this notion.

Chapter 8

CONCLUSION

8 CONCLUSION

Conclusion about the Project is drawn in the following Chapter.

The whole notion being the ideology of autonomous mobility has been attributed to helping bring an increase in efficiency and productivity. SASC moreover provides a greater output rate and brings down the cost. Through the use of the handheld Beacon, the user is given another feature of ease to work around with the cart [27]. The Graphical User Interface (GUI) is kept simple and sleek, along with the feature of touchscreen, the user does not require any fancy training to be interactive. He can just take the cart for the ride around the store, enjoying from aisle to aisle. SASC enables a more efficient approach for a valuable resource, making the task less tedious and saving time.

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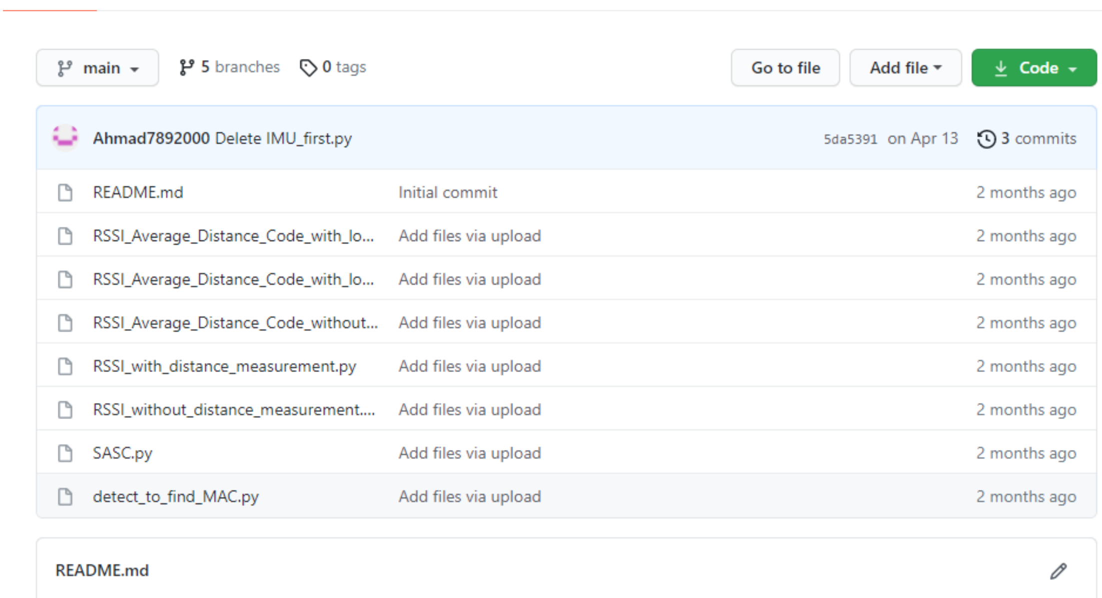
Git Hub Repository



All the Codes used in the project can be found in the Following GitHub Repository

https://github.com/Ahmad7892000/SASC

SASC

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