CartEase

Capstone Project Report

END-SEMESTER EVALUATION

Submitted by:

(102103127) Sukhmani Arora

(102103135) Aadi Jain

(102103141) Akshat Gupta

(102103143) Amogh Rew

(102103145) Samarjeet Singh Gandhi

B.E Fourth Year, COE

Under The Mentorship of
Dr. Tarunpreet Bhatia
Associate Professor, CSED

THAPAR INSTITUTE
OF ENGINEERING & TECHNOLOGY
(Deemed to be University)

Computer Science and Engineering Department
Thapar Institute of Engineering and Technology, Patiala

December 2024

ABSTRACT

The needs of increased efficiency, better customer experience, and integration of advanced technologies are driving the retail industry toward dramatic transformation. On this reinventing landscape, CartEase adds an innovative smart shopping cart solution meant to revolutionize the shopping experience for consumers and retailers alike. The project will design a smart shopping cart that will house scanning and paying technology within the cart itself. This means that customers will scan items while they go about shopping, pay safely without hassle, and totally avoid the long queues at the checkout counter.

CartEase is all about facilitating shopping, making it more convenient and time effective. The hassle of long queues at checkout lines is eliminated with the provision of facilities for shoppers to finish transactions right in the cart, making the whole shopping experience much easier and more enjoyable. Besides, there is also real-time product location assistance with the smart cart that aids customers in a store to locate required products, further adding to the improvement in their shopping experience.

Apart from customer convenience, a shopping cart Easy has a few very strong advantages to help large retailers. Our smart cart comes fitted with data analytics capabilities for helping retailers gain insight into shopper behavior, their product preferences, and ways of refurbishing store layouts to be more effective. These insights will equip retailers with the capability to optimize store operations, tailor marketing strategies, and make decisions for driving sales and satisfaction. Also, it had advanced security features that prevent robbery and ensure the reliability of the transactions, hence enhancing trustworthiness in shopping.

This report contains the conceptualization, design, and expected impact that CartEase could have on the retail industry. It looks at the key features of the smart cart—such as its Web app integration and the customizable interface based on the divergent needs in different retail environments. The paper has also analyzed the market potential for CartEase by pinpointing possible users and customers to whom the solution would be beneficial, like according to this study: busy consumers looking for convenience and retailers wanting to achieve operational efficiency.

The report further outlines the expected financial performance of CartEase, including a balanced revenue model where incomes are to be accrued from the sales of smart shopping carts and subscription-based data analytics services. A cost structure, revenue streams, and cash flow projections have been done to show the financial viability and sustainability of the project.

Finally, CartEase is a new retail revolution that gives the cutting-edge solution for the critical challenges and elevates the shopping experience. While retail continues to change, CartEase certainly has a significant contribution to make toward changing the way people shop in the future, providing a win-win solution for both consumers and retailers. This summary report spells out the objectives, features, and potential impact of the project, thus emphasizing its value as an innovation that can transform the retailing sector.

DECLARATION

We hereby declare that the design principles and working prototype model of the project entitled CartEase is an authentic record of our own work carried out in the Computer Science and Engineering Department, TIET, Patiala, under the guidance of Dr. Tarunpreet Bhatia and during the course of our 6^{th} and 7^{th} semester (2024).

Date: 18/12/2024

Roll No.	**Name**	**Signature**
102103127	Sukhmani Arora	
102103135	Aadi Jain	
102103141	Akshat Gupta	
102103143	Amogh Rew	
102103145	Samarjeet Singh Gandhi	

Counter Signed By:

Mentor:

Faculty Name: Dr. Tarunpreet Bhatia

Associate Professor

Computer Science and Engineering Department

TIET, Patiala

ACKNOWLEDGEMENT

We would like to express our thanks to our mentor Dr. Tarunpreet Bhatia. She has been of great help in our venture and an indispensable resource of technical knowledge. She is truly an amazing mentor to have.

We are also thankful to Dr.. Shalini Batra, Head, Computer Science and Engineering Department, the entire faculty and staff of the Computer Science and Engineering Department, and also our friends who devoted their valuable time and helped us in all possible ways towards successful completion of this project. We thank all those who have contributed either directly or indirectly towards this project.

Lastly, we would also like to thank our families for their unyielding love and encouragement.

They always wanted the best for us and we admire their determination and sacrifice.

Date: 18/12/2024

Roll No.	**Name**	**Signature**
102103127	Sukhmani Arora	
102103135	Aadi Jain	
102103141	Akshat Gupta	
102103143	Amogh Rew	
102103145	Samarjeet Singh Gandhi	

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

DL	Deep Learning
OTP	One-time password
POS	Point of sale
RFID	Radio Frequency Identification
UPI	Unified Payments Interface
YOLO	You Only Look Once

INTRODUCTION

1.1 Project Overview

The world is becoming fast, and so is technology with changing times; consumer behavior is changing at a rapid pace. This therefore presents the continuous challenges that retailers have to keep up within the industry. For retailers to remain in business, innovation must be continuous in providing the solutions to meet the rising expectations of the modern shopper. This project looks to introduce a pioneering smart shopping cart that not only meets these demands but will also anticipate the future needs of both customers and retailers. Our smart shopping cart is designed to revolutionize the conventional retail experience by providing a seamless, efficient, and user-friendly way, thus becoming an apt replacement for the more conventional methods of shopping.

At the heart of our innovation lies advanced object detection technology using models like YOLO [1], which have proved effective in similar applications. It makes our smart cart self-scanning, where items are automatically scanned when the customer shops, and they can be paid for immediately through the cart itself. Unlike the older systems that use RFID scanners and ZigBee modules [2],[3],[4] , our approach eliminates all traditional checkout lines. It offers an easier and much more streamlined way of shopping in stores, moving and wandering around easily and effortlessly, without frustrating customers by standing in long queues to pay.

However, the advantages of our smart shopping cart extend much further than just improving the customer experience. Our solution is designed to arm retailers with robust data analytics that give deep insights into consumer behavior, based on a number of patterns—like product popularity, customer movement within the store, and shopping trends—which, if understood properly, can be used to guide inventory, in-store placement, and marketing strategy decisions. This data-driven approach not only helps bring operational efficiency but also opens up new ways to augment sales and boost overall profitability.

Our project is, therefore, the great leap forward that the retail industry needs. We strongly believe that through state-of-the-art technology and customer convenience, we will change how people shop and, indeed, change retail experience expectations. We envision this smart shopping cart to be a first step into the future where shopping will be faster, easier, more insightful, and more profitable for retailers. This is a solution that imagines a world where hassle in shopping will be at a minimum and focuses squarely on value and satisfaction for both consumers and retailers.

1.2 Need Analysis

Inefficiencies at Checkout: One of the critical pain points for shoppers is lengthy and cumbersome checkout processes. Frustrations stemming from the lines at the checkout counters generally translate into a lousy shopping experience. More importantly, such lines can be endless during peak hours or busy seasons, which might test even the most patient customer's tolerance. The need for a solution to rid traditional check-out lines has never been greater.

Customer Convenience Expectations: Living in times when convenience determines everything, consumers anticipate their shopping to go as smoothly as possible. With e-commerce on the rise, customers have become used to easy online transactions where items are bought with just a few clicks on a computer or phone. So retailers must up their game to provide comparable levels of convenience if they do not want to lose clients. Smart shopping cart technology

Could help close the gap between online and offline purchases by providing checkout-free experience in physical stores.

Challenges Faced by Retailers: A retailer has to efficiently manage the inventory so as to maintain the optimal quantity of stock and prevent the 'out-of-stock' situation. However, the traditional methods of inventory management are almost never real-time and thus the system remains inaccurate and inefficient. In the absence of correct information about which products are the best-selling or

Customer preferences, it would be difficult for them to determine the location of where to place the product, how to promote it, and when to re-supply it. A solution using wireless technology referred to as a "smart shopping cart" (SSC) will revolutionize this process by detecting and analyzing high-velocity shopper data in real-time so that retailers are able to improve their inventory management processes to maximize sales.

Opportunities for Data-Driven Insight: With respect to the highly competitive business environment, gathering and analysing shoppers' information has become an upper hand for any retail business. Since all consumers tend to behave differently, like different things, and follow different patterns of purchasing, brands have constantly been changing their marketing strategies with prospects of meeting their consumers' requirements at hand. These intelligent trolleys could serve as an immense source of information concerning shopping habits of customers: to which kind of product are they more disposed? How is the traffic around the store moving? So much intelligence gathered like this could enable a host of merchandising decisions, from improving the customer experience to enhancing store operations, among many others, which would enhance Net Promoter Score while driving more revenue into the company.

Competitive Pressure and Innovation: At present, in a world where the supermarkets are more competitive than ever, the road to survival is through innovation. Being ahead of the game and staying a step ahead of customer expectations means adaptability. Those retailers who do not adjust to the changing ways of consumers and new technologies can be left behind by their peers who make innovation a priority. The ability of smart shopping cart technology to give retailers the ability to distance themselves by providing a very contemporary shopping experience—one that is incomparable to any other in the industry—makes them leaders in this progressing landscape of retail. This means such retailers must adopt innovation and foster technology-driven solutions supporting it.

1.3 Research Gaps

- **Not Much Exploration in Novel Security Features:** Although few publications mention secure methods of payment, such as OTP and UPI, there remains an insufficiency in providing a total or overall solution with regards to high-level security to prevent possible fraud in the entire shopping session, such as product authentication, prevention of theft in the cart, etc.

- **Not Much Emphasis on the Aspect of Real-time Data Analytics:** Most of the existing solutions are focused on the checkout process and fall short in the application of real-time data analytics which can provide actionable insights to retailers in their pursuit of addressing optimal shopper behaviour, product placement, and inventory management.
- **Scalability and Network Dependency:** Solutions that require deep learning and neural networks can be computationally demanding and need strong network connectivity; hence, they do not scale so well in larger retail setups or in areas where internet connectivity is usually shaky.
- **Consumer Adaptation and User Experience:** Although some of the research does address affordability and ease of use, there is, of course insufficient work done in understanding the adaptability of the consumer to these new technologies more in the context of UI design, overall shopping experience enhancement.
- **Limited Consideration of Diverse Retail Environments:** Most the proposed solutions are now specific to a setup, like malls or supermarkets. Therefore, it is not easy to modify or use them in other retail settings like shops or non-traditional settings.
- **Overemphasis on Hardware Solutions:** Many works are focused on hardware implementation like RFID, cameras, and neural compute sticks but leave out the software-driven or hybrid approaches, which could otherwise serve flexible and cost-effective solutions.
- **Neglect of Cross-Platform Integration:** There is little interest in trying to explore how smart shopping carts may be integrated with other digital platforms, like mobile apps or even online stores themselves, toward achieving a seamless omnichannel retail experience.
- **Neglect of Customer Feedback Integration:** Few studies consider the integration of mechanisms for customer feedback in the smart cart system itself for constant improvements and personalization of shopping experience through real time user inputs.
- **Underexplored Customization Options for Retailers:** The retailers have customization options by default to make the smart cart technologies ready

to their needs and branding, but little has been explored so far. That eventually kills the potential diffusion across different sectors in retail.

1.4 Problem Definition and Scope

In today's high-speed retail environment, from long lines at the checkout to finding items and a lack of personal touch, there are many common challenges to a seamless in-store experience. At the same time, retailers lose much productivity in inventory management, loss prevention, and the little capability to acquire real-time consumer insights. These challenges stem from shopping carts and checkout systems that have failed to evolve at the same speed as consumers' expectations—a problem causing frustration for customers and lost opportunities in business.

Considering the challenges outlined above, our project proposes the development of a Smart Shopping Cart system that will utilize advanced technologies such as object detection and real-time analytics, along with secure payment processing. This ingenuity cart shall bring ease to the shopping experience with its features, where it scans products in real-time, creates automatic bills, and offers secure payment directly from the cart, eliminating checkout lines traditionally used. This will also include real-time product location assistance and enhanced customer convenience, with a data analytics platform that captures valuable insights for retailers in understanding shopper behaviour to assist inventory management, store layouts, and promotional strategies.

This project will be characterized by hallmarks of improvements in customer experiences and operational efficiency, which shall also be abided with fraud prevention mechanisms to secure the deal against thefts. Further, it shall also embody the scope to test the scalability of smart shopping cart systems across various retail environments; from small shops to large supermarket stores, there will be customization settings available according to the needs of the different retailers in using the technology.

The project will be pilot tested in selected retail locations to receive feedback from customers and retailers to fine-tune the system before rolling out more widely. This means that a seamless, efficient, and very secure experience of shopping at the very best level is achieved in retail, serving the interests of consumers and businesses equally.

1.5 Assumptions and Constraints

Following are the assumptions and constraints that are applicable we began our project with

Table 1: Assumptions and Constraints

S.No.	Assumptions
1.	The customers will readily adopt the smart shopping carts due to convenience and time saving.
2.	Retailers will be interested in integrating the smart cart to their stores which can improve operational frequency.
3.	The system can be scaled to be implemented across different sectors.
	Constraints
1.	Development and deployment should stay within the budget.
2.	The system should integrate smoothly with existing technologies without disrupting other operations.
3..	The system should be designed for minimal downtime with ease of maintenance and support.
4..	The system should provide a reliable experience across different retail and customer scenarios.

1.6 Standards

- IEEE 830: A manual for the development of SRS. Functional and non-functional needs are included in the software requirements definition. It may also include a set of use cases that explain the user interactions that the programme must deliver in order for the interaction to be complete and fulfilling.

- IEEE 1471: Architecture description of software-intensive systems is recommended as a best practice.
- IEEE 1462: Evaluation and selection of CASE tools: a guideline
- IEEE 1059: Guide for software verification and validation plans
- IEEE 1219: Software maintenance
- IEEE 802.11: It specifies a set of media access control (MAC) and physical layer (PHY) protocols for implementing wireless local area network (WLAN) computer communication and is part of the IEEE 802 set of local area network (LAN) technical standards. The standard and modifications form the foundation for Wi-Fi-branded wireless network equipment and are the most extensively utilized wireless computer networking protocols in the world.

1.7 Approved Objectives

- To create a hardware prototype with an integrated controller board with cameras and screen for interaction.
- To develop a machine learning model to detect and recognize various items placed in the shopping cart.
- To develop the user interaction software to accurately manage the addition or removal of items within the user's shopping cart and integrate it with the hardware.
- To analyze large volumes of data collected from smart shopping cart to provide various valuable insights to the retail owner.

1.8 Methodology

- **Input Feed:** An input feed will be taken by the camera module attached to the cart which will help in viewing the image of the item added to the cart.
- **Pre-Processing:** The image collected by the camera module would be pre-processed in which any unwilling distortions, edge detections, detection of whether an item has been added in the cart or not would be settled and the image will be enhanced for further processing.
- **Product Detection:** The product will be detected with the help of YOLOv10 which would be trained on a dataset which will contain the various images of the grocery items.
- **Product Recognition:** The product image will first be detected by the model and then be recognized after comparing with the images contained in the dataset.

1.9 Project Outcomes and Deliverables

- **Grocery Items Detections Model:** A camera unit running computer vision algorithms for object detections, mainly items that are in the super-marts, using models such as YOLOv10 etc.
- **Client Interface:** The user-friendly interface at your fingertips,

  tailor-made for your comfort. Our interface permits you to easily get vital data about your cart items, your subtotal and essential details.
- **Upgraded Security Measures:** Trained DL models enable the system to detect any unusual behaviour which includes an attempt of theft or dupe. Proper warning and error mechanisms ensure that any such attempt is duly notified to the local staff and store owners.
- **Integration with Payment System**: Our shopping cart framework consistently coordinates with payment systems, guaranteeing secure and hassle-free transactions. The cart itself would become the checkout and POS for the customer, removing the need for long checkout lines.

1.10 Novelty of Work

- **Revolutionizing Retail:** Imagine a basic need shopping involvement where you do not have to traditionally check barcodes at checkout. This cutting-edge vision is getting to be a reality with the presentation of a new shopping cart. These imaginative carts consistently coordinated innovation to convert the shopping experience for both retailers and customers.
- **Fraud Detection:** Advanced DL models and integrated sensors enable us to detect anomalies in items that are being put in the cart and with proper warning and error systems the store owners and staff will be notified of a possible attempt of theft.
- **Unlocking Important Insights:** By collecting and analysing client behavior, such as item inclinations, retailers pick up profitable data to optimize store formats, oversee stock viably, manage inventory, and personalize the shopping experience.
- **Adaptability for Different Needs:** The magnificence of this innovation lies in its adaptability. The carts can be customized to fit different retail situations, from sprawling grocery stores to compact comfort stores. This guarantees their significance and adequacy over a wide extent of businesses in any case of measure or item selection.
- **A Transformative Solution:** The integration of cutting-edge innovation, security measures and information analytics capabilities are all combined in a single attachment that can easily be added to existing shopping cart inventory of the retail shop owners. This further reduces the cost to implement our solution and shift from the traditional cart system.

REQUIREMENT ANALYSIS

2.1 Literature Survey

In the area of smart shopping carts, research has been centered around reducing checkout times and managing inventory using RFID technology, deep learning for automatic product identification, as well as IoT integration. Hence improving the shopping experience as well as providing valuable data analytics to the retailers. However, difficulties may be seen when these technologies are wholly integrated in areas such as safety, scalability and usability. Thus, we will develop a comprehensive solution to address these gaps through our project.

2.1.1 Theory Associated with Problem Area

Smart shopping cart systems are developed with respect to certain theoretical areas: automation, machine learning, the Internet of Things, and human-computer interaction.

- **Automation and Efficiency:** Automation theory majorly reduces the complexity in retail operations. Automating the checkout process by using smart shopping carts removes the necessity for human labor, cuts human errors, and eventually scales up performance. Automated systems in retail support quick execution in transactions and free up staff who might have been occupied with customer service and inventory management.
- **Machine learning and Object Detection:** Machine learning, in particular object detection algorithms, is most pertinent to identify, categorize, and recognize the products in real-time using the smart shopping cart. This is attributed to techniques such as YOLO, which stand behind the recognition of items at a very precise moment when they are being put into the cart, offering real-time accuracy and promptness to both the consumer and the system.
- **Integration of IoT:** The IoT architecture integrates the system in which

  the smart shopping cart would be interoperable with devices that are to be supported while being connected with the shopping cart. It behaves like supporting the store inventory system, updating the availability of products, and may even provide customers with the facilities of tracking their behavior to better shape the system in a responsive and dynamic retailing environment.

- **Human-Computer Interaction:** The smart shopping cart stands to be a great success or failure based on the principles of HCI that provide the specified system's nature as user-friendly and intuitive. The creation of interfaces for easy interaction, facilitated by touch screens, mobile apps, or even voice commands, will allow access to such technology to a much broader population, including people having no or very low use of technology.
- **Data Analytics:** Another critical theoretical contribution is in the field of retail data analysis. Retailers can infer customer preferences, the popularity of products, and shopping patterns by looking into the data in the smart shopping cart system. It can pay back in ways like denoting the space allocation and purposing for running stores and even the management of inventories in much better and improved ways along with targeted marketing strategies.

2.1.2 Existing Systems and Solutions

It was a series of new retail industry-related innovative systems adding much dimension to the customer's shopping experience, all targeted toward better convenience, efficiency, and security.

- **Automatic Product Detection with Secure Payment System:** Autodetection of Products in Shopping Carts and Highly Secure Payment Platforms: Some smart carts have autodetection of the products in them, coupled with very secure payment platforms such as OTP-based and UPI-based. These carts facilitate checkout and make transactions possible within the cart itself, avoiding the billing desk.
- **RFID-Embedded Shopping Carts:** Implemented the RFID technology to reduce queuing time at the billing counter. It embedded a system for real-time monitoring of items dropped into the cart; therefore, customers could review on the spot and pay for their purchases, hence minimizing human error and increasing the speed.

- **Affordable and Adaptable Smart Carts:** This comprises smart carts equipped with cameras and item detection through neural networks, which have been pre-trained without any reliance on network connectivity. Those low-cost carts bring flexibility and usability to store owners for many retailers.
- **Deep Learning-Based Billing Carts:** Tackling the issue of perishable items, the system implements deep learning and camera technology that identifies items **and** their weights straight from the cart. It creates bills automatically, so there is no hassle during shopping.
- **Walk-Out Technology with Sensor Fusion:** Some systems build upon Amazon Go's inspiration, wherein deep learning and sensor fusion allow for a checkout-free shopping experience. Each customer is automatically billed as they leave the store, offering unmatched convenience.

IoT-Driven Automatic Carts: The combination of IoT and robotics allows these carts to be able to follow customers autonomously, enhancing usability, especially for elderly or physically challenged people, and incorporates smart item detection to improve the overall shopping experience.

2.1.3 Research Findings for Existing Literature

Table 2: Literature Survey

S.No.	Roll Number	Name	Paper Title	Tools/Technology	Findings	Citation
1	102103145	Samarjeet	An Intelligent Shopping Cart with Automatic Product Detection and Secure Payment System	Object detection, biometric authentication, payment integration	The article introduces a sophisticated shopping cart that combines automated product identification with a reliable payment mechanism.	Subudhi, and Ponnalag [5]
2	102103145	Samarjeet	Intelligent Shopping Cart using IoT Technology	Radio frequency Identification	The article shows how IoT technology may turn shopping carts into intelligent systems with automated product	Mounica et. al. [6]

					detection	
3	102103143	Amogh	Smart Shopping Cart	Neural network, object detection	The paper comes to the conclusion that smart shopping carts	Belibov and Tudose [7]
4	102103141	Akshat	Deep Learning based Automated Billing Cart	DeepLearning, RFID	Deep learning in automated billing carts enhances product recognition accuracy and simplifies checkout with real-time charging.	Ragesh, et. al. [8]
5	102103135	Aadi	Shop and Go: An innovative approach towards shopping using Deep Learning and Computer Vision	Self checkout systems, transaction tracking	Deep learning and computer vision automate product recognition, real-time cart management, and quick checkout, creating a seamless "Shop and Go" experience.	Shekokar, et. al. [9]
6	102103127	Sukhmani	Automation of Shopping Carts using Technology	Internet of Things (IoT), Ultrasonic sensors with raspberry pi	The paper reveals that automating shopping carts using RFID, sensors, and IoT improves the shopping experience by	Padma, et.al. [10]
7	102103127	Sukhmani	IoT applications on secure smart shopping system	radio frequency identification (RFID)	The design requirements of a smart shopping system were identified, build a prototype system to test functionality, and design a secure communication protocol to make the system practical.	Ruinian, et. al. [11]
8	102103135	Aadi	Smart Cart with Automatic Billing, Product Information, Product Recommendation Using RFID & Zigbee with Anti-	RFID and ZigBee	A smart shopping cart system that will keep the track of purchased products and online transaction for billing. There is a centralized system for the	Yewatkar et. al. [12]

			Theft		recommendation and online transaction. A RFID reader at the exit door is equipped for anti-theft.	
9	102103141	Akshat	IoT-Based Smart Shopping Cart Using Radio Frequency Identification	Radio Frequency Identification (RFID) sensors, Arduino microcontroller, Bluetooth module, and Mobile Application	This experimental prototype is designed to eliminate time-consuming shopping process and quality of services issues.	Shahroz et. al. [13]
10	102103127	Sukhmani	RFID-Cloud smart cart system	OLED display, Arduino Mega 2560 board, a specifically designed PCB, a Wi-Fi	The queuing delays in major supermarkets or other shopping centers are reduced by means of an Electronic Smart Cart System through RFID technology	Yerlan and James [14]
11	102103141	Akshat	IoT based smart shopping trolley with mobile cart application	13.56 MHz HF RFID tag reader and receiver	The proposed Smart Cart in this paper, is capable of generating bill using IoT along with the mobile cart application. With the use of this mobile application and trolley, customer can make bill payment in no time.	Kowshik a et. al. [15]
12	102103143	Amogh	Development of smart shopping carts with customer-oriented service	Radio-frequency identification (RFID) tags	Through the searching function of SSC, the purchasing efficiency and navigation aid in the mall can be effectively supplied. The automatic	Chiang et. al. [16]

					billing service can be done by the SSC and the stored shopping data will be transmitted to the cloud server of shopping 1 mall.	

2.1.4 Problem Identified

The requirement to attach an RFID tag to every product in the current smart cart systems is a significant barrier because it's a laborious and complicated procedure. Our technology solves this problem by identifying products without individual RFID tags by utilizing the YOLOv10 object detection paradigm.

Moreover, it is frequently necessary to completely redesign current carts in order to integrate new smart cart systems, which presents challenges for retailers in terms of expense and transition. Our proposed solution comprises an attachable component that can be added to already-existing carts to address this issue. This strategy not only saves time and money on capital expenses, but it also helps stores make the move more smoothly.

2.1.5 Survey of Tools and Technologies Used

Literature surveys reveal a range of tools and technologies that have been applied to the development of smart shopping cart systems, all of which contributed to different aspects of the retail experience.

- **RFID Technology:** It has been used in quite a number of works and is, therefore, quite important in the automation of the detection of products in shopping carts. It allows real-time scanning and updating of items placed in the cart, greatly reducing manual scanning and consequently human error.
- **Biometric authentication:** Some systems use a combination of techniques from biometric methods, such as fingerprint scanning and Unique Identification Numbers, to identify the shopper. This provides enhanced security, avoiding any kind of unauthorized payment, and will help speed up checkout procedures.
- **Deep Learning and Computer Vision:** More and more often, deep learning algorithms and computer vision techniques are being integrated into smart carts. Such technologies make it possible to develop sophisticated

object detection, allowing the carts to self-identify items using visual data and not by barcodes or RFID tags. This comes in very handy, especially where perishables like fruits and vegetables are involved, for they are hard to tag traditionally.

- **IoT Integration:** IoT is essential in enabling connectivity between smart shopping cart systems, their payment systems, and inventory management.IoT ensures real-time communication between the carts and the store's systems, allowing seamless transactions and more efficient inventory tracking.
- **Ultrasonic Sensors and Pattern Recognition:** It also makes use of ultrasonic sensors and pattern recognition so that this cart is more usable, mostly for people with mobility issues. These technologies enable the cart to track down the user on its own and increase the shopping experience for the elderly and the physically challenged.
- **Neural Compute Sticks:** Advanced systems make use of neural compute sticks, which make use of deep learning models to process information right on the cart. This hardware accelerates neural network inferences for faster and more accurate item recognition without any need for external processing power.
- **Secure Payment Systems:** Many secure payment systems, such as OTP and UPI, have been integrated into smart carts, which make the transactions safe and quick within the cart itself. This eliminates any checkout counter, thereby increasing the convenience aspect and decreasing the time spent in the store.

2.2 Software Requirement Specification

2.2.1 Introduction

2.2.1.1 Purpose

This Software Requirement Specification document has been formulated for our smart shopping cart system to evidently determine software requirements. This paper stipulates technical and functional requirements that will be able to guide the development process, so it serves customers and retailers effectively. The detailed requirements of this paper are toward the creation of a seamless and efficient shopping experience while at the same time providing data insight values to retailers.

2.2.1.2 Intended Audience and Reading Suggestions

This document is intended for the development team, all project stakeholders, and any other person who takes part in the development, design, implementation, and deployment of the smart shopping cart system. A developer and an engineer will be more interested in the sections that describe the overall description and the interface requirements. Nonfunctional requirements are mostly useful to the QA teams for checking that the system performance meets the expected standard. These include the project introduction, product perspective, and the cost analyses areas. These will best help stakeholders, particularly retail partners, to understand the scope and potential impacts that the project presents.

2.2.1.3 Project Scope

A radically transformed retail shopping experience in which a smart shopping cart that intuitively recognizes items through sophisticated object recognition technology automatically scans the items, processes customer transactions, and collects data for retailers. This system replaces the traditional checkout line and thereby increases the speed and convenience of the buying process. It will also provide very deep consumer behavior insights at different instances, thereby helping the retail outlets optimize their operations and strategies. The solution design will be scalable, adaptive, and can thus be upgradable for future enhancement, such as integration with a mobile application and deploying advanced data analytics.

2.2.2 Overall Description

2.2.2.1 Product Perspective

The intention behind the smart cart system is to facilitate retailing, notwithstanding the customer's enjoyment. It brings in hardware, like cameras and sensors, and software that handles some aspects of it, such as item detection, user interface, and payment processing. This system will interact

with a cloud database for fetching product details and storing transaction data. It also has a data analytics module to provide the insights on the behavior of a customer. The system has been designed to fit into the current retail environments and enhance the shopping experience with as little change as possible in the store's current layout.

2.2.2.2 Product Features

Some of the important features of the smart shopping cart system are:

- **Automatic Item Detection:** Items placed in the cart are automatically detected and logged inside with the help of advanced object detection technology.

- **Ease of Payment:** Customers can easily pay right from their cart, eliminating the need to stand in a line.
- **Real-Time Data Collection:** These data include the knowledge of shopping behavior, such as popular products and the way customers move around the shop.
- **Data Analytics:** Trend reports on shopping behavior will provide an insightful report so that retailers could make effective decisions regarding inventory and other promotional activities.
- **User Interface:** The cart is integrated with an easy-to-use touch screen with the user's current shopping list, the cost of all products currently in the cart, and the available options to pay in different modes.
- **Future Integration:** A mobile application is planned, which will integrate with the cart. Customers can manage their shopping experience from their phones.

2.2.3 External Interface Requirements

2.2.3.1 User Interfaces

It opens avenues for a user interface that even a tech-estranged person can handle. Some of the main features designed are:

- **Touch Display:** The interface on the screen will display all information regarding the products in the cart, which have been scanned, price, and all relevant discounts to be applied.
- **Interactive Payment Options:** A customer is provided with various options to complete the payment, which will be quick and safe.
- **Feedback Mechanisms:** The cart produces both visual and audio feedback to confirm actions, including when an item is scanned and when a payment is completed.

2.2.3.2 Hardware Interfaces

Interactions come with a number of key hardware components, specifically:

- **Cameras:** High-resolution cameras take pictures of items placed in the cart to enable an object detection system to identify and log each product.
- **Weight Sensors:** They verify the weights of items in the cart, identifying items precisely and avoiding mistakes or pilferage.
- **Central Processor** (Raspberry Pi 4): It is the main processing unit handling all images, data processing, and storage, as well as controlling the user interface.

2.2.3.3 Software interfaces

This smart shopping cart software will interface the system into the following unified functionalities:

- **Object Detection Software:** YOLO model is utilized to do item detection in real time.
- **Cloud Database:** The system fetches product details from a cloud-based database and saves the transaction details.
- **Payment Gateway:** Payment would be done securely through an integrated gateway with multiple support methods.
- **Data Analytics Platform:** The cart collects data and processes it to be shown on an analytics platform so that it is prescriptive to the retailers.

2.2.4 Other Non-functional Requirements

2.2.4.1 Performance Requirements

The system would be reliable and efficient for the performance:

- **Real-Time Operation:** The scanning and logging of an item must incur as little delay as possible, about 1 second per item.
- **Scalability:** The system should be able to support multiple carts for a single store without degradation of performance.
- **High Availability:** The system will always be ready for use during store hours with an uptime of 99.9%.

2.2.4.2 Safety Requirements

Safety is a top concern of the smart shopping cart system:

- **Electrical Safety:** All elements and materials applied should meet safety standards, in order to prevent electrical hazards.
- **Physical Stability:** The cart should be stable and easy to maneuver, even when fully loaded with items.
- **Data Protection:** User data, especially payment information should be protected with encryption and secure communication protocols.

2.2.4.3 Security Requirements

Security measures are cardinal to hold the integrity of the system:

- **Data Encryption:** All the communications between the cart and the cloud database should be encrypted very well so as to ensure sensitive information protection.
- **User Authentication: To** unlock the system's administrative functions, very solid authentication mechanisms are required.
- **Anti-Fraud Measures:** The system involves checks like weight verification so that fraud is avoided.

2.3 Cost Analysis

- Weight Sensor - 176/-
- Camera Module - 3505/-
- Raspberry pi 4 - 3500/-
- Arduino mega 2560 - 1000/-
- Screen Module - 2800/-
- ESP32 Module: 570/-

2.4 Risk Analysis

The analysis of the risk determines the problems that might occur during the development and implementation of the smart shopping cart system and preparation of the methods of reducing the risks.

2.4.1 Technical Risks

- **Probability of Object Detection Model Failures:** The probability of detecting some objects is relatively high, and it may result in poor customer experience. A way to minimize this is to do testing and model updating on a regular basis.
- **System Latency:** Delays in processing may really bug users. Topping the system architecture for lower latency will be very significant for smooth operations.

2.4.2 Operational Risks

- **Customer Adoption:** Customers may resist new technology. User-friendly design and in-store demonstrations will ease the transition.
- **Data Security:** Breaches could compromise sensitive information. Strong encryption and secure authentication along with regular security audits will be paramount in protecting user data.

2.4.3 Financial Risks

- **Budget Overruns:** It is a risk that the budget may be overrun because of the costs incurred that were not previously thought of. Proper planning, monitoring at each stage, and backup with contingency funds will reduce the risk factor.
- **Return on Investment:** The smart carts will not be worth it if they do not attract enough users or retailers. Small pilot programs and a lot of market research will prove their worth to directly gain more users.

METHODOLOGY

3.1 Investigative Methods

In our endeavor to design and develop a new intelligent shopping cart, we realized that an organized and systematic approach was necessary to reach our objectives. Our investigative approach included both qualitative and quantitative research methods, a strategy that was validated by our need for a thorough understanding not only of the technological aspects but also consumer behavior and preferences regarding shopping experiences. This double emphasis enabled us to develop a stronger solution that tackles diverse aspects of the retail setting.

Furthermore, we participated in conversations with a wide variety of retail industry specialists, such as store supervisors, technology suppliers, and experts in consumer behavior. These interviews shed light on various practical challenges encountered when implementing intelligent shopping solutions, such as assimilation with current systems, staff education, and customer approval. They also emphasized the notable discrepancies in existing systems that our project could efficiently tackle, giving us a clearer focus for our development endeavors.

The development of the shopping cart attachment involved several systematic steps, including data collection, data annotation, model training, and real-time implementation on hardware. The primary goal was to create a system capable of detecting and classifying items placed in a shopping cart using computer vision techniques, specifically leveraging the YOLO (You Only Look Once) object detection framework. Additionally, a secondary objective was to demonstrate the feasibility of item-specific recognition within the cart. The following sections detail the methodology employed to achieve these objectives.

Proof of Concept and Future Extensions

The successful deployment and operation of both models demonstrated the feasibility of real-time item detection and recognition on a portable, low-power device like the

Raspberry Pi. The proof of concept for item-specific recognition established a foundation for scaling the system to recognize a wider array of products.

Future work involves expanding the dataset to include more items, improving model accuracy and efficiency, and integrating additional functionalities such as price calculation and inventory management. Exploring advanced techniques like edge computing and integrating more powerful hardware could further enhance system capabilities and performance.

3.2 Proposed Solution

The suggested solution is a cutting-edge intelligent shopping trolley system created to greatly improve the retail shopping experience by using both automation and sophisticated data analysis. This advanced system combines an intelligent trolley equipped with object recognition technology, self-scanning abilities, and an integrated payment processing system. By utilizing these advanced technologies, customers can engage with retail settings in a smoother and more effective way. The outcome is an improved shopping experience that offers customers unmatched convenience, efficiency, and valuable information for retailers, ultimately changing the way shopping is done.

3.2.1 System Structure

At the heart of this intelligent shopping cart system is a sophisticated object recognition technology that uses camera sensors to automatically identify products as they are placed inside the cart. This creative approach removes the conventional and frequently boring requirement for barcode scanning, making the shopping process more efficient. All details about the product and the pricing are securely stored in a cloud-based database, which enables instant access and updates while shopping.

Additionally, the smart cart includes a user-friendly interface that showcases the current shopping list, the total price of chosen items, and the available payment methods. Customers can finalize their transactions directly from the shopping cart using a variety of accepted payment methods, including tap-and-go payments. This feature eliminates the inconvenience usually linked with lengthy checkout lines, enabling a more effective and enjoyable shopping experience.

3.2.2 Data Analysis

A crucial element of our proposed solution is the incorporation of cutting-edge data analytics, which gives retailers valuable insights into customer behavior. The intelligent trolley will monitor customer movements throughout the store, recording the order of items chosen and the duration spent in various areas. This abundance of information will be processed and analyzed to produce comprehensive reports on shopping trends, product popularity, and individual customer preferences.

Merchants can use these insights to enhance inventory management practices, upgrade store layouts, and customize marketing strategies to better align with customer needs. Moreover, live monitoring of shopping patterns allows retailers to introduce flexible in-store promotions and make timely price changes depending on consumer behavior and demand.

3.2.3 Improving Customer Experience

Crafted with the consumer in mind, our intelligent shopping trolley aims to enhance the shopping experience itself. The automated scanning and payment processes greatly decrease the amount of time shoppers spend in stores, making shopping trips faster and more pleasant. The user-friendly interface is created for ease of use, guaranteeing that customers of all ages can confidently interact with the technology without any worries.

Moreover, the system improves customer experiences by providing customized promotions depending on past shopping history. For example, if a consumer regularly buys healthy items, the system can recommend similar products or offer discounts on frequently purchased items. This customized approach not only enhances the shopping experience but also promotes customer loyalty, prompting consumers to come back for future visits. Ultimately, the intelligent shopping cart system signifies a notable advancement in retail technology, merging convenience, effectiveness, and customization to establish a truly contemporary shopping setting.

3.3 Work Breakdown Structure

The work breakdown structure (WBS) of our smart shopping cart project essentially revolves around four main modules, each further branched into a more granular form of tasks that will result in the accomplishment of the project deliverables. These are: Hardware Integration, Software Development, Data Analytics, Testing & Deployment.

3.3.1 Hardware Integration

- **Task 1: Component Selection**: Find and source all the hardware required for the project. Some major components that will be used include a Raspberry Pi 4, several camera modules, a couple of weight sensors, and display units.
- **Task 2: Assembly**: Assemble the smart cart with the help of the chosen components, thus providing a working prototype.
- **Task 3: Connectivity Setup**: Burn the code for wireless communication between the cart and the main database so that there is a continuous flow of data.

3.3.2 Software Development

- **Object Detection Module**: Develop the system of object detection with the help of the information known, which has been commonly used, every time a scan of the product has to be made by the cart.
- **User Interface Design**: Design and implement the cart user interface to be user-friendly and accessible.
- **Payment Gateway**: Implement a gateway to make payments by a set of customers to complete transactions originating from the cart.

3.3.3 Data Analytics

- **Data Collection Framework**: Develop a framework for collecting and storing data on the interaction of customers with the cart.
- **Analysis Algorithms**: Create algorithms for analyzing shopping patterns, product popularity, and consumer behavior.
- **Reporting Tools**: Create and install reports and visualization tools to harness and process valuable information.

3.3.4 Testing and Deployment

- **Task 1:** System Testing: System-wide testing of the hardware and software will be done to identify problems, modifications, and other constraints.

- **Task 2:** Pilot Deployment: Implement the smart cart within a controlled retail environment to conduct pilot testing, gather community feedback, and make any necessary adjustments.
- **Task 3:** Full-Scale Deployment: Implement the smart cart across multiple retail locations in a centralized manner, with training and support for a smooth deployment.

3.3 Tools and Technology

We want to realize our smart shopping cart by relying on some selected tools and technologies in combination, with each chosen to satisfy a need that corresponds to a requisite of the project.

3.3.1 Hardware Tools

- **Raspberry Pi 4**: This is the main computing hardware that will be responsible for the overall control of the smart cart, processing all the object detection algorithms, and controlling the data transmission.
- **Camera Modules**: Cameras help take an image of items kept in the cart so that the object detection system can easily identify the products.
- **Weight Sensors**: Embedded to ensure that the detected items are similar in weight to the objects held inside the cart, thereby supporting a layered addition of accuracy to the system.

3.3.2 Software Tools

- **YOLO** (You Only Look Once): A class of high-end models to identify and register items being put into the cart for detection. It is fast, and sufficiently suitable for real-time applications in retail shops. Real-time object detection is one of the features.
- **Python**: It will be the primary programming language for developing the software part of a smart cart: from the object detection module and user interface down to the data analysis tool.

- **TensorFlow**: An ML framework with the YOLO model training and optimization to understand a variety of products under numerous conditions

3.3.3 Data Management Tools

- **Pandas**: It is a Python library used to manipulate and analyze data. This aids in sorting out the data coming from the carts raised for one to easily identify valuable insights by retail.
- **Matplotlib:** The plotting library for the Python programming language for plotting visualizations of the analyzed data. Matplotlib particularly assists in the representation of insights, thus providing clear and understandable expressions of the trends and patterns to be able to make the rationale used for informed decision-making by the retailers.

4.1.1. Block diagram

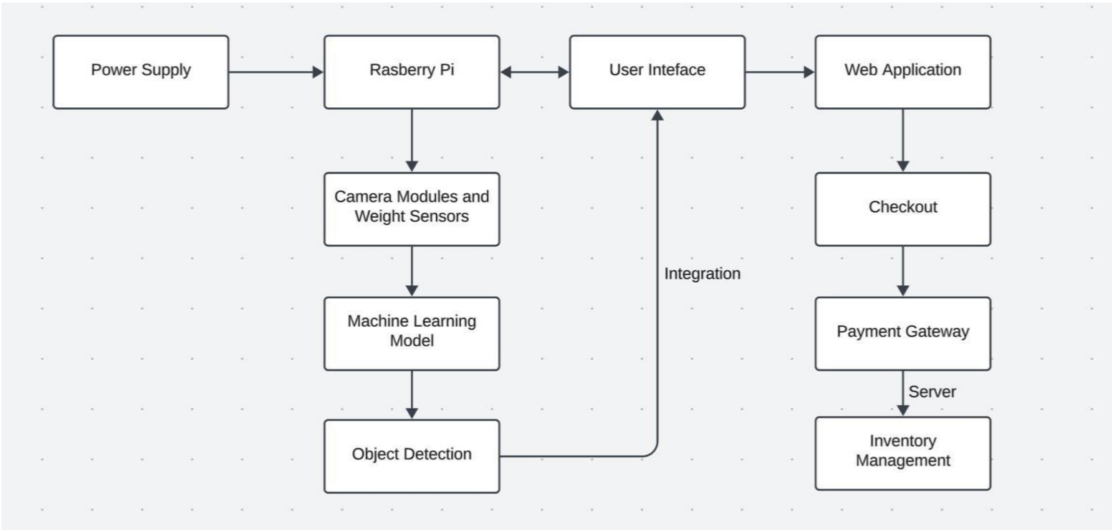


Figure 1: Block diagram

Fig 1. Presents a block diagram of our system

4.1.2 Use case diagram

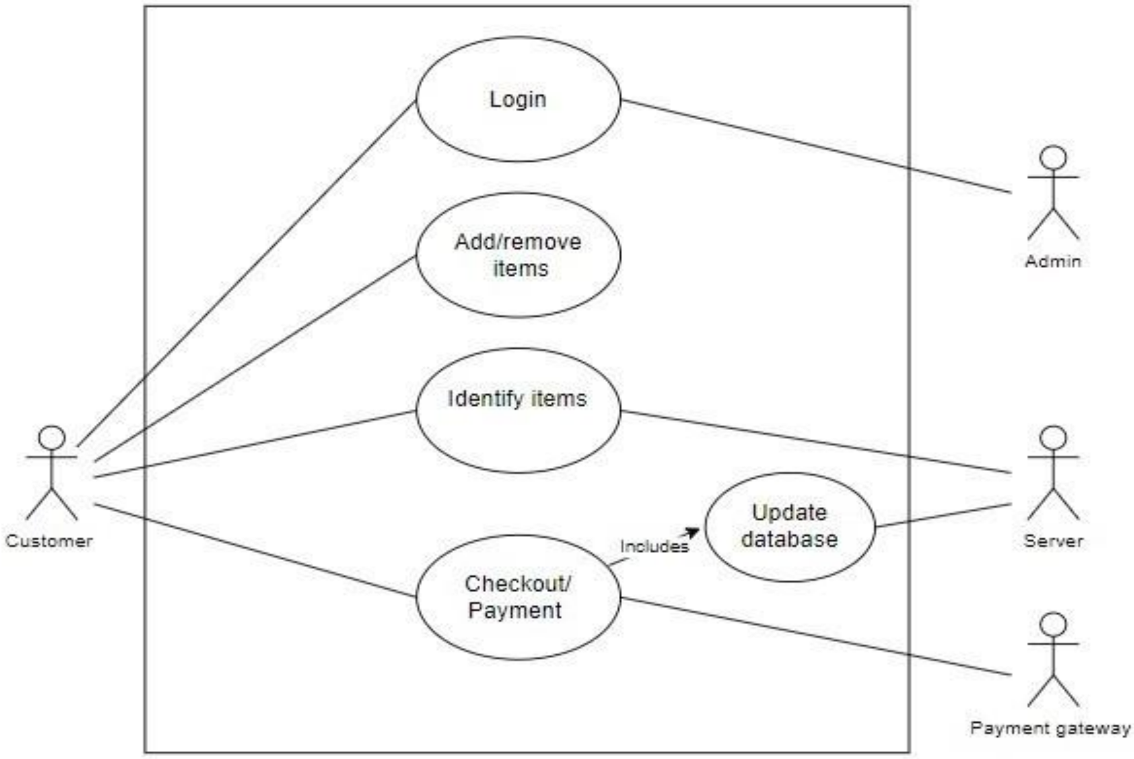


Figure 2: Use case diagram

Figure 2 shows the ways in which the user can interact with the system using the use case diagram.

4.1.3 Activity/ Swimlane diagram

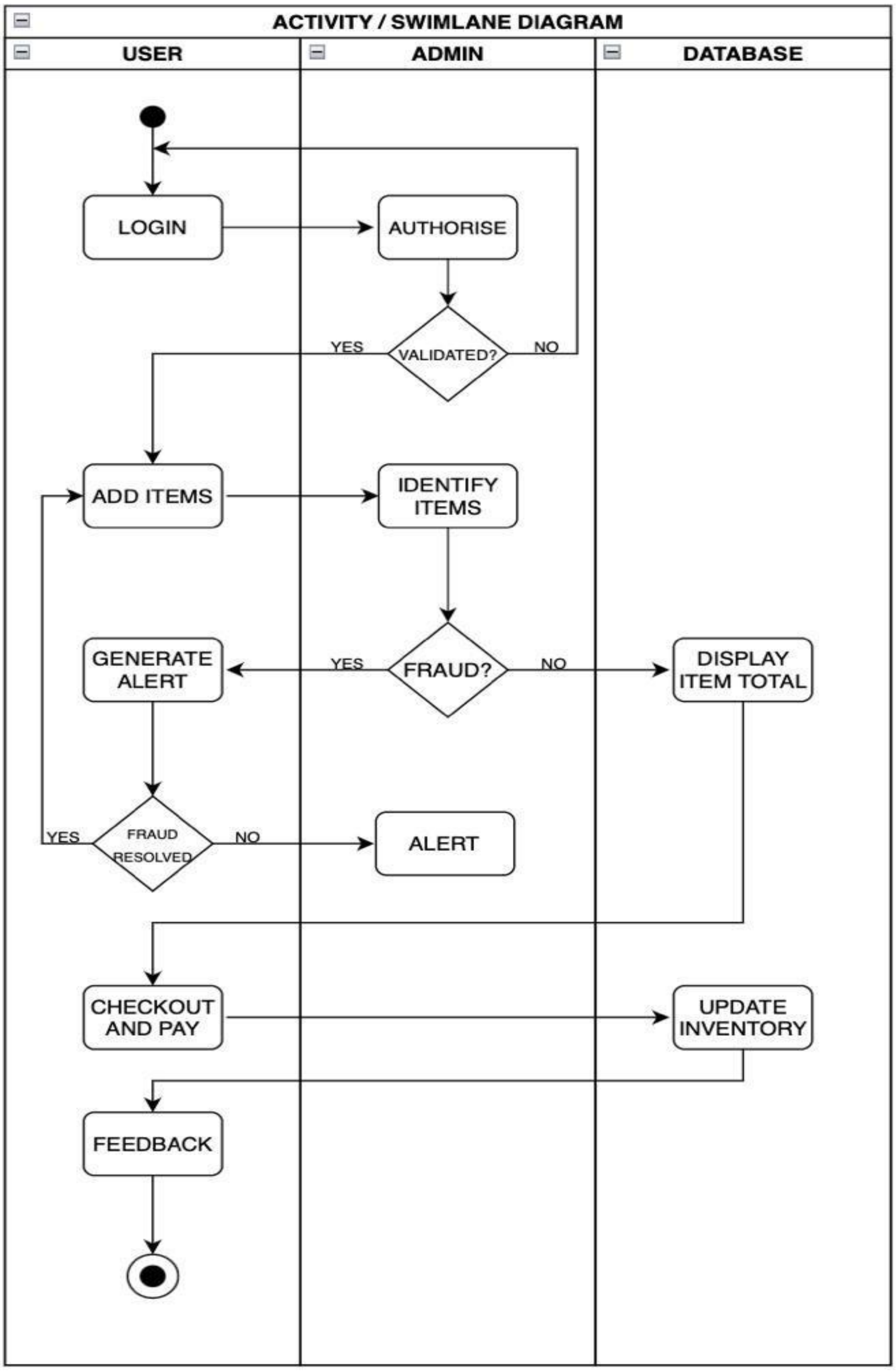


Figure 3: Activity diagram

4.1.4 Design Level Diagram

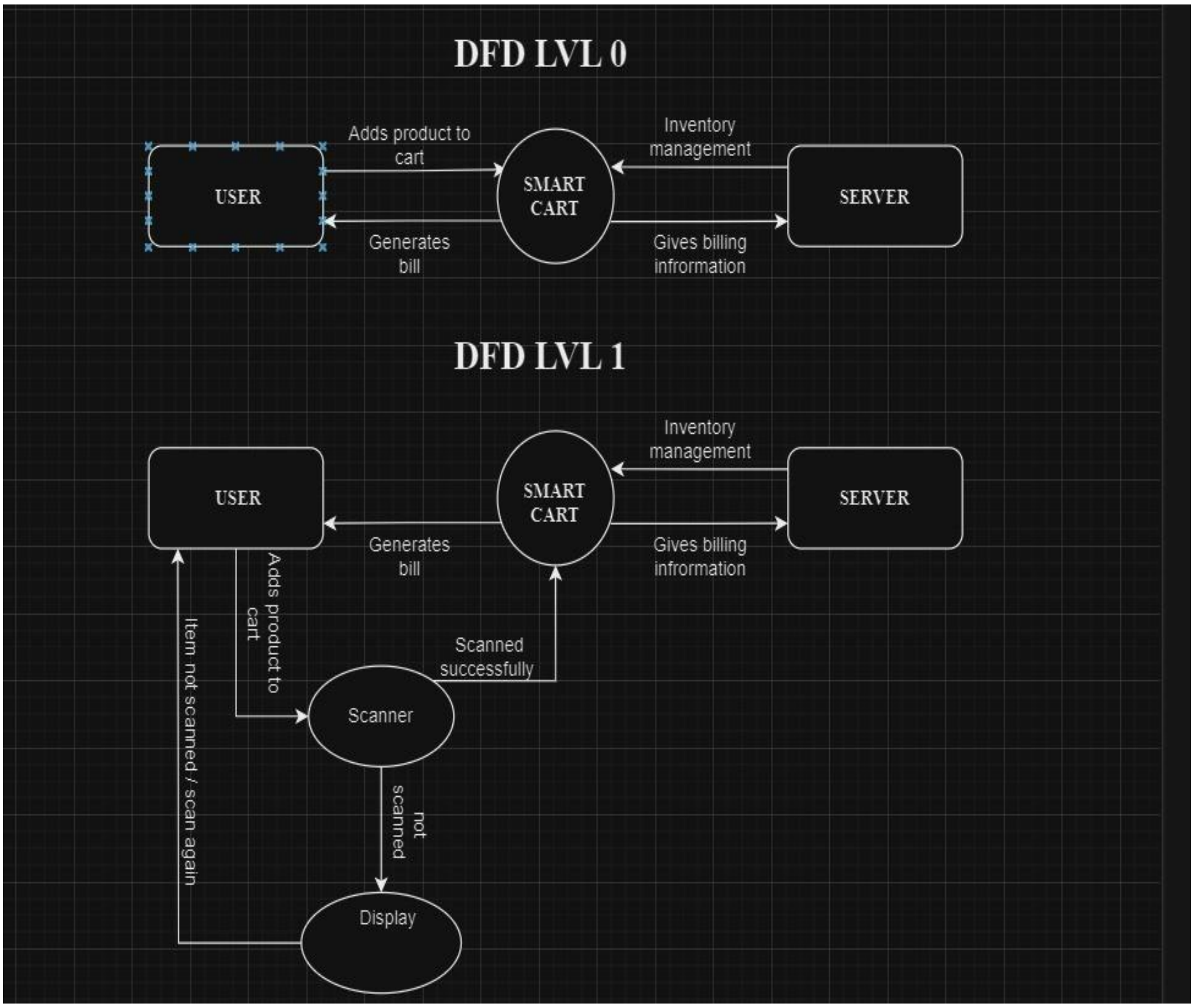


Figure 4: Data Flow Diagrams

4.1.5 User Interface Diagrams

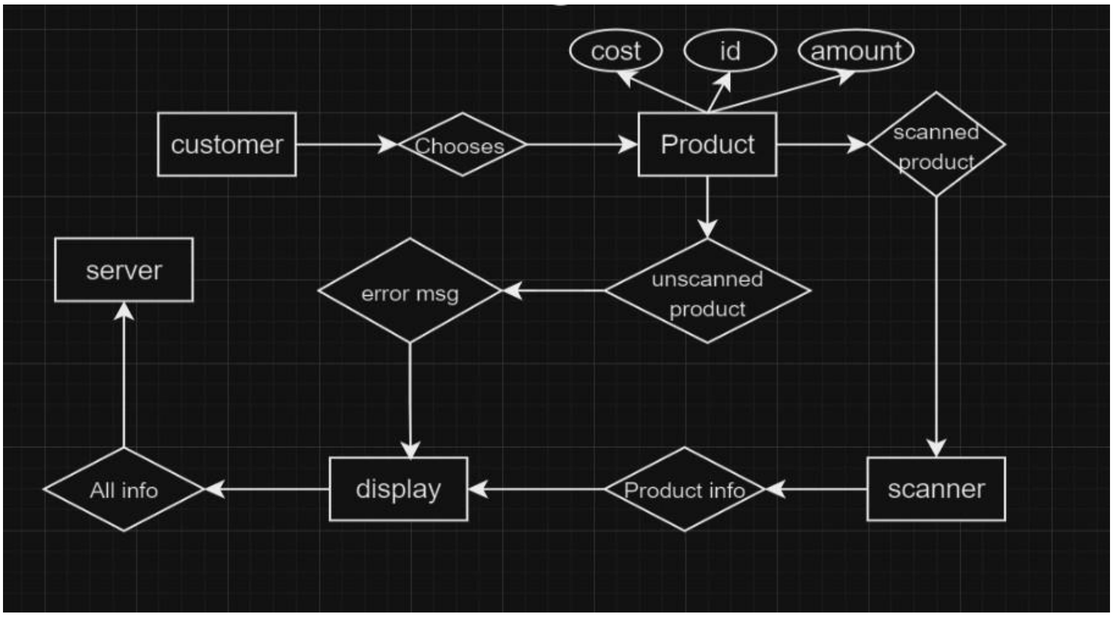


Figure 5: User interface diagram

4.2 Snapshots of Working Prototype

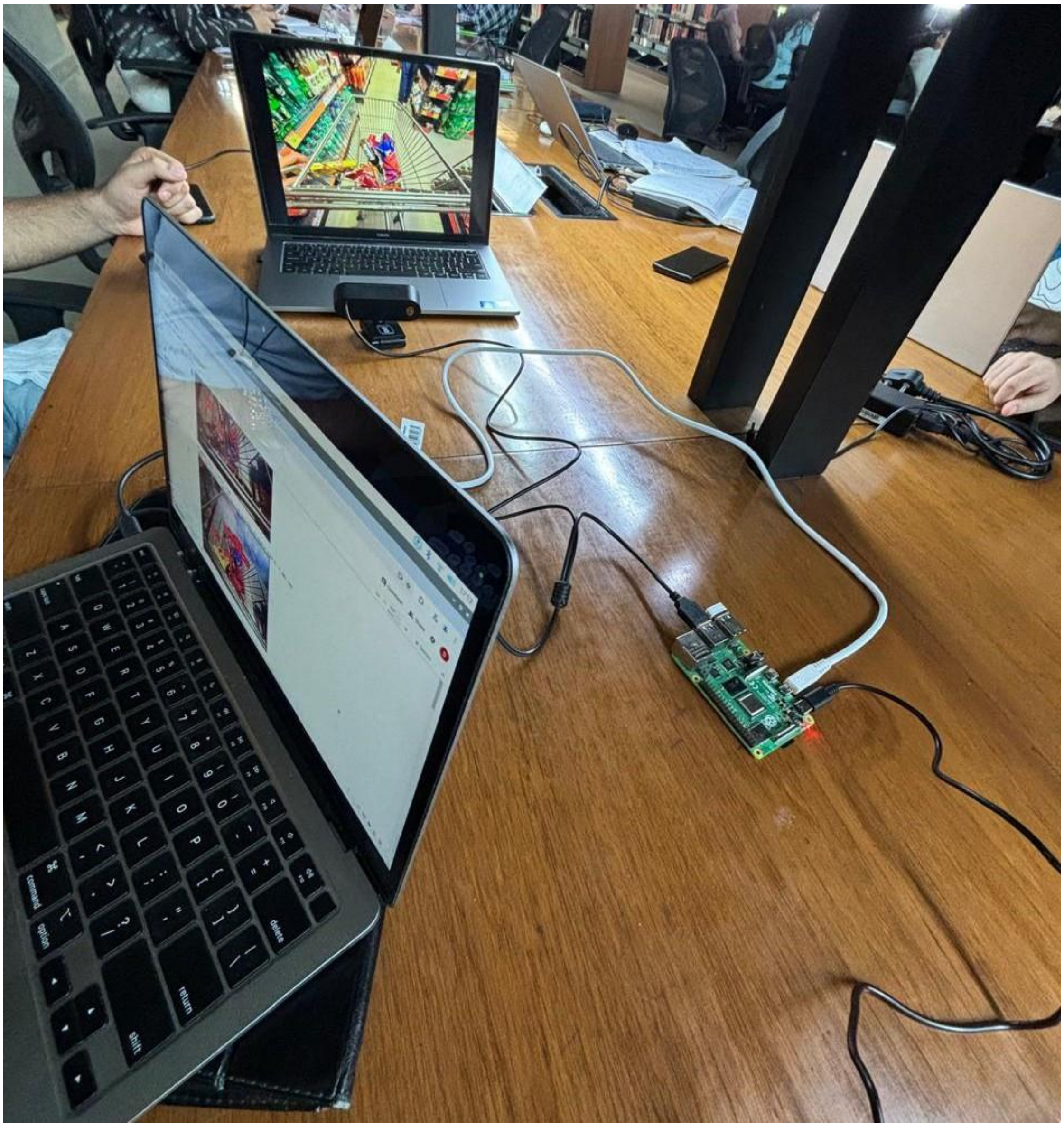


Figure 6: Preliminary Setup

Raspberry Pi is running in the laptop on the left where the model is running which is making inferences on the live video feed provided by the camera attached to Raspberry Pi

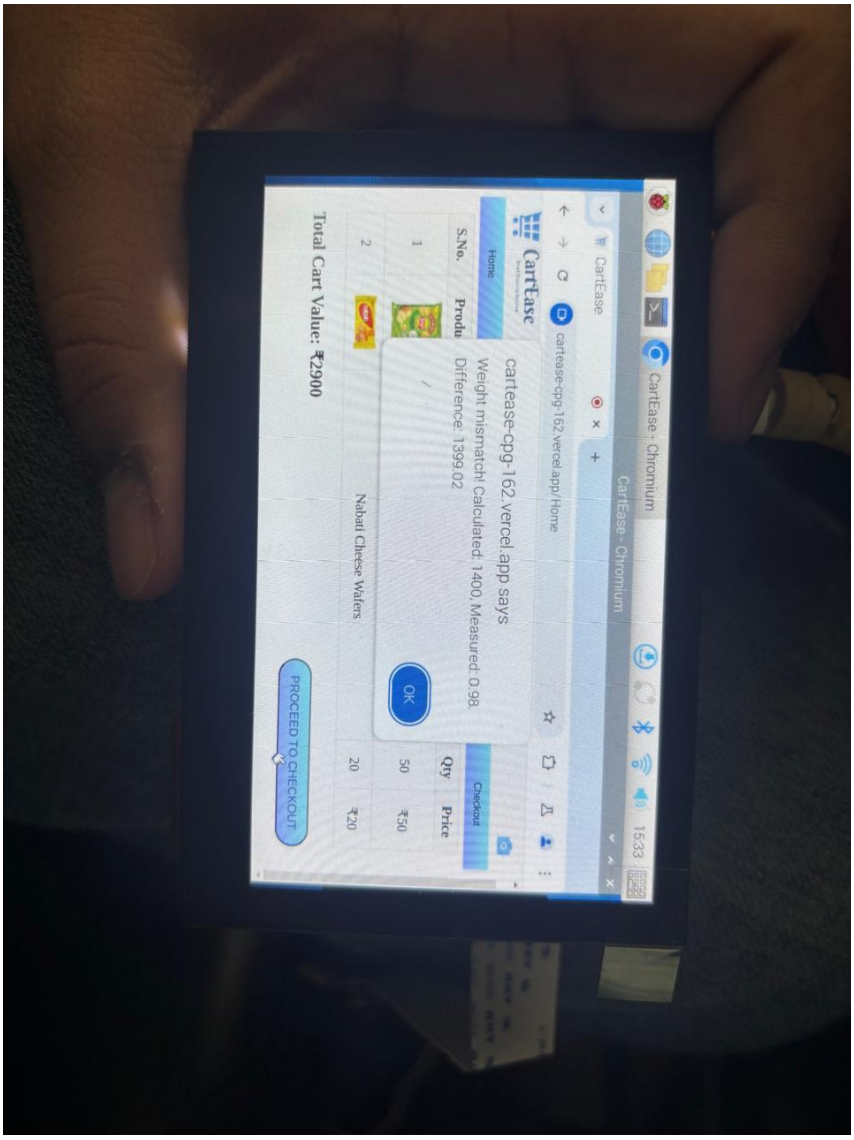


Figure 7: Raspberry Pi Screen displaying User Interface

Implementation and Experimental Results

5.1 Experimental Analysis

5.1.1 Data

5.1.1.1 Data Collection

To train accurate and reliable object detection models, a comprehensive dataset was essential. The data collection process involved visiting a local shopping mart to capture a diverse set of images that represent real-world scenarios of items being placed into and removed from a shopping cart.

Approximately 650 high-resolution images were captured using a camera to train our first model which would detect items and the cart itself. Along with these images another set of 414 images were captures to help train another model which would recognize the various items in the cart.These images encompassed various angles, lighting conditions, and item arrangements to ensure the model's robustness and generalizability. The scenarios included different types and quantities of items being added to or removed from the cart, simulating typical shopping behaviors. Care was taken to include a wide variety of products to capture the diversity encountered in a real shopping environment.

5.1.1.2 Dataset Creation

Following data collection, the images underwent a meticulous annotation process to prepare them for training the object detection model. Manual annotation was performed using annotation tools such as Roboflow, which allows for precise bounding box creation around objects of interest within each image.

The annotation process involved labelling items such as the "cart" and the items present in it. This binary classification was critical for the model to discern whether an item had been successfully added to the cart or not. Consistency and accuracy during annotation were paramount to ensure high-quality training data, directly impacting the model's performance. Annotators adhered to strict guidelines to maintain uniformity across all annotations, carefully outlining object boundaries and verifying labels for correctness.

For the secondary objective of item-specific recognition, a separate set of 414 images was collected and annotated. These images focused exclusively on a particular item chosen as a proof of concept for detailed item recognition. The annotation for this dataset involved labeling the specific item consistently across various positions and orientations within the cart to train the model effectively for precise identification.

Further the dataset went through various Pre-Processing and Augmentations steps for a better and robust model training.

Some of the Pre-Processing steps that were employed were:

- Auto-Orientation
- Resize
- Auto-Adjust Contrast: Using Contrast Stretching

Further some of the Augmentations that were applied are as follows:

- Blur: Up to 0.7px to 2px
- Brightness Variation: Between -20% and +20%
- Noise: Up to 1.53% of the pixels

With these steps we managed to create datasets with 1116 in one and 1095 photos in the other dataset on which the model will finally train.

5.1.1.3 Model Training

The annotated datasets were used to train two separate YOLO models tailored to their respective tasks. YOLO was selected due to its efficiency and real-time object detection capabilities, making it suitable for deployment on hardware with limited processing power such as the Raspberry Pi.

Figure 8: Annotation on Roboflow

The cart area is annotated as "cart" and is marked with the color purple. The items in Cart have also been marked.

5.1.1.4 Training the Presence Detection Model

The first model aimed to detect and classify items based on their presence in the cart. The 1095-image dataset served as the training data for this model. The training process involved several steps:

1. Preprocessing: The images and corresponding annotations were preprocessed to match the input requirements of the YOLO framework. This included resizing images and performing image augmentation.

2. Model Configuration: Appropriate YOLO configuration files were set up, specifying parameters such as the number of classes, input image size, and training hyperparameters including batch size, and number of epochs.

3. Training Process: The model was trained using a supervised learning approach, employing techniques such as data augmentation to enhance model robustness. Data augmentation included operations like rotation, scaling, and flipping to simulate various real-world conditions and improve the model's ability to generalize.

4. Evaluation and Validation: Throughout training, the model's performance was evaluated using metrics like Mean Average Precision (mAP) and Recall, and Precision. A validation set, consisting of a subset of the annotated images, was used to monitor overfitting and guide hyperparameter tuning.

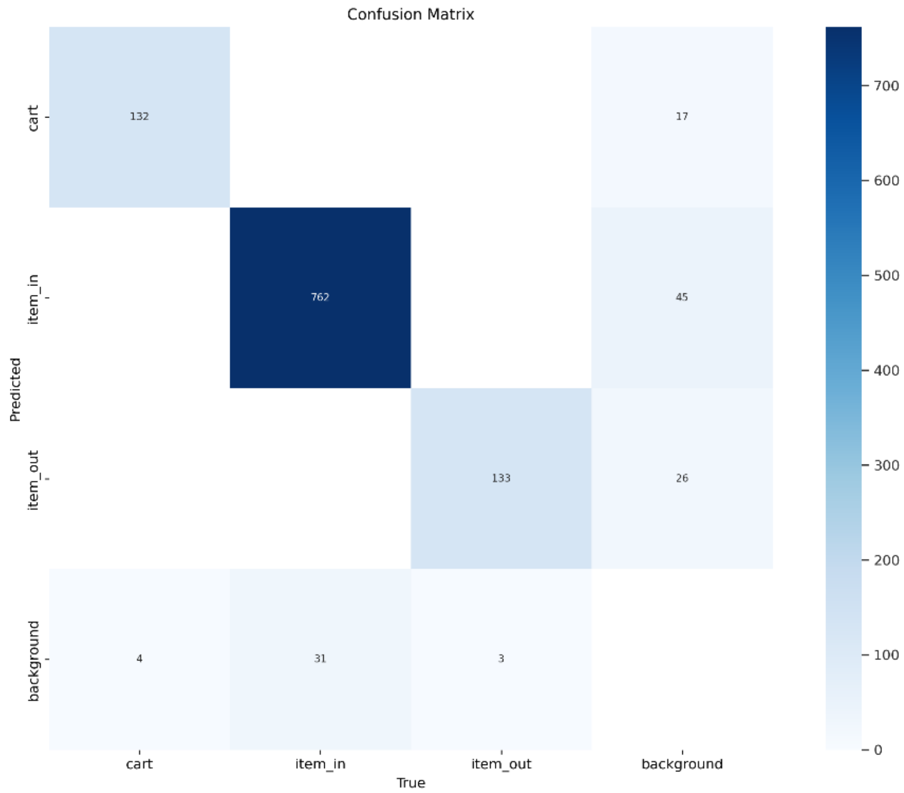


Figure 9: Confusion Matrix- Presence Model

5.1.1.5 Training the Item-Specific Recognition Model

The second model focused on recognizing a specific item within the cart. Utilizing the 1116-image dataset, the training process mirrored that of the first model with adjustments tailored for fine-grained object recognition:

1. Preprocessing and Configuration: Similar preprocessing steps were undertaken, with model configurations adjusted to reflect the single-class detection task.

2. Training and Augmentation: Given the smaller dataset size, extensive data augmentation was employed to expand the effective training data and improve the model's ability to recognize the item under various conditions.

3. Performance Evaluation: The model's accuracy in identifying the specific item was rigorously tested, ensuring high precision and recall rates essential for reliable item recognition.

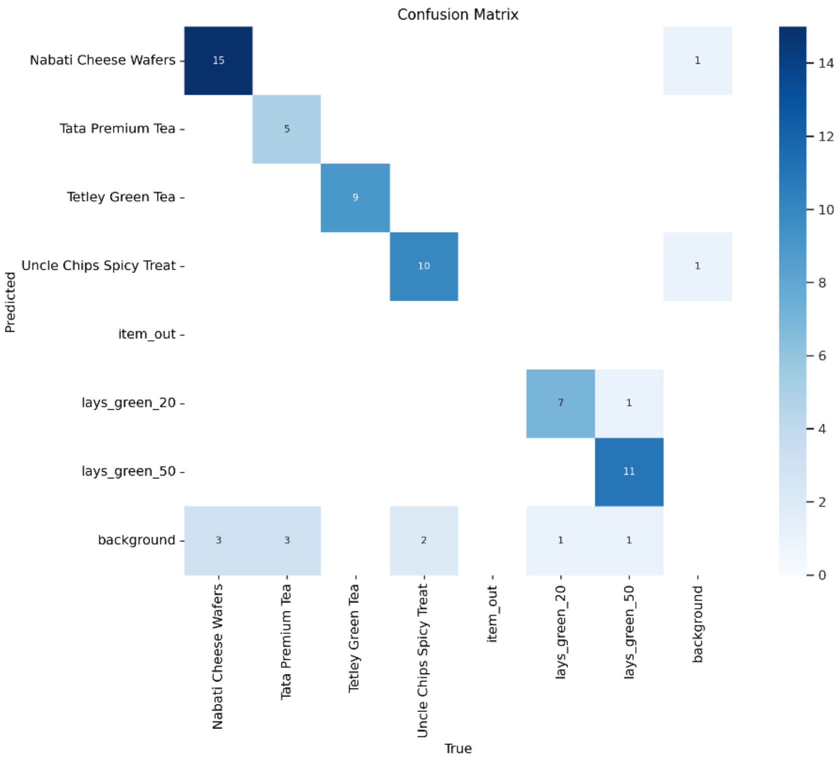


Figure 10: Confusion Matrix-Recognition Model

5.1.1.6 Implementation on Raspberry Pi

For real-time inference, the trained models were deployed on a Raspberry Pi equipped with an attached camera module and a display screen. Implementing live object detection on such resource-constrained hardware posed several challenges, which were addressed through careful optimization and system design.

System Setup

1. Hardware Configuration: The Raspberry Pi was set up with necessary peripherals, including the camera module for capturing live video feed and the display screen for outputting detection results. A microcontroller facilitated the integration and control of hardware components.

5.1.1.7 Implementation of Weight Sensors

The implementation of weight sensors in the smart shopping cart system is a crucial component for ensuring the accuracy and reliability of item detection and checkout processes. Weight sensors serve multiple purposes, including verifying the presence and weight of items placed in the cart, preventing theft, and ensuring accurate billing.

5.1.1.8 Selection of Weight Sensors

The first step in implementing weight sensors was selecting the appropriate type of sensors for the smart shopping cart. Load cells, which are capable of measuring weight with high precision, were chosen due to their accuracy, sensitivity, and durability.

5.1.1.9 Integration with the Microcontroller

Once the weight sensors were selected, the next step involved integrating them into the physical structure of the shopping cart. The sensors were strategically placed at the base of the cart to ensure they could accurately measure the weight of all items added or removed. This placement allows the sensors to detect changes in weight as items are placed into or taken out of the cart, which is crucial for maintaining an accurate inventory of the items being purchased.

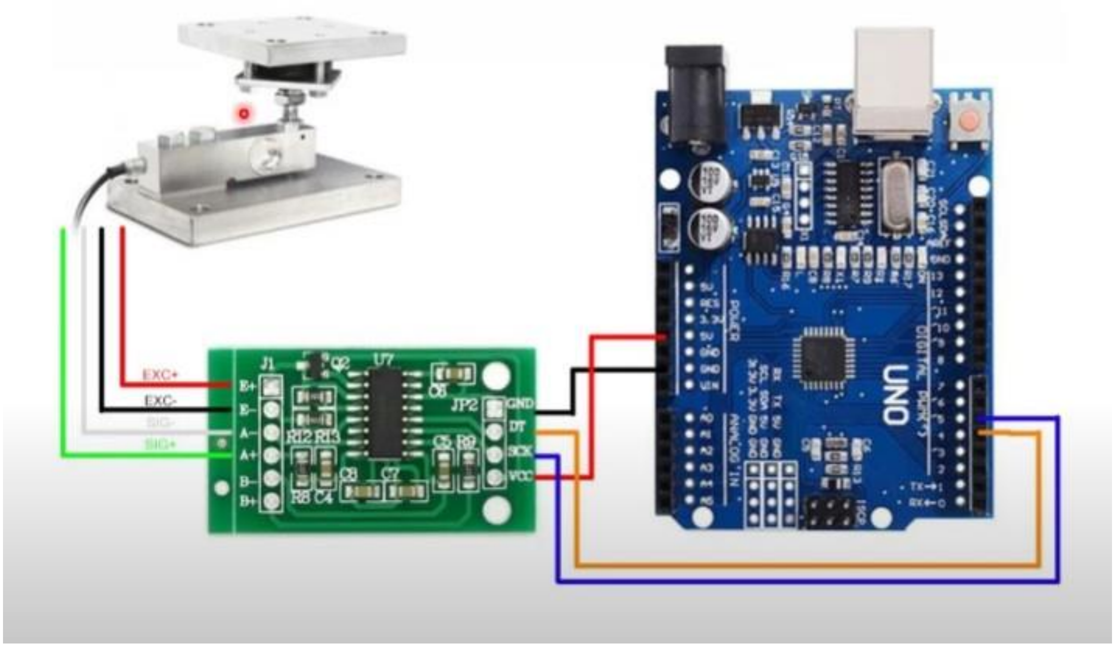


Figure 11: Connection of load cell, HX711 and Arduino

5.1.1.10 Calibration and Configuration

To ensure the weight sensors provide accurate readings, calibration is an essential process. The sensors were calibrated using known weights to establish a baseline measurement and to configure the system to account for the cart's own weight. This process involved programming the microcontroller, typically a part of the Arduino, to zero out the cart's weight before starting the shopping process. Calibration ensures that any additional weight detected by the sensors corresponds only to the items added by the customer.

5.1.1.11 Real-Time Weight Monitoring

The weight sensors continuously monitor the total weight of items in the cart. This real-time monitoring allows the system to detect any discrepancies between the weight of scanned items and the actual weight detected by the sensors. If a discrepancy is found, the system alerts the customer through the cart's display screen, prompting them to rescan the item or check for any unscanned items. This feature

helps prevent accidental omissions or intentional theft, ensuring that all items are accounted for accurately.

5.1.2 Performance Parameters

The performance of the project is evaluated based on various quantitative and qualitative metrics that reflect the system's accuracy, efficiency, and reliability. These parameters ensure the system meets practical requirements and performs optimally in real-world scenarios.

---

1. Model Parameters

- **Definition:** Detection accuracy refers to how correctly the system detects an item in the captured frames.
- **Importance:** Ensures reliable performance of the **detection models**.
  - **Metrics Used:**
    - **Precision:** Measures how many of the detected items are correctly classified.

      Precision=TP/TP+FP

    - **Accuracy:** Measures the proportion of correctly classified instances out of all instances.

      Accuracy= TP+TN/TP+FP+FN+TN

    - **Recall (Sensitivity):** Measures how many actual items are detected.

      Recall=TP/TP+FN

    - **F1-Score:** Combines precision and recall into a single performance score

      F1 Score=2·Precision·Recall/Precision+Recall

- **Real-Life Application:** If 10 items are added to the cart and the system detects 9 as correctly, the recall is high, but missing even 1 item highlights the need for improvement.

---

2. Inference Time (Latency)

- **Definition:** The time taken by the system to process one image frame and provide a classification result.
- **Importance:** Critical for real-time operation in a shopping cart environment

where users expect instantaneous results.

- **Measurement:** Measured in **milliseconds (ms)** per frame.
- **Factors Affecting Latency:**
    - **YOLO Model Size:** Lighter models (e.g., YOLOv5 nano) run faster but may compromise accuracy.
    - **Hardware Performance:** Performance of Raspberry Pi or other microcontrollers influences processing speed.
    - **Frame Resolution:** Higher-resolution images take longer to process.
- **Optimization Achieved:** By using a lightweight YOLO model and optimized code on Raspberry Pi, inference time is minimized to ensure smooth user experience.

Parameter	Metric	Target
Detection	Accuracy, F1-Score	> 85%
Inference Time (Latency)	Milliseconds per frame	< 300 ms per frame
Processing Speed	Frames per second (FPS)	1-2 FPS
Alerts	User-friendly feedback	Accurate & timely

Table 3: Performance Metrics

5.2 Working of the Project

5.2.1 Procedural Workflow

The procedural workflow outlines the sequence of steps that the system follows, from capturing images to providing actionable outputs. This ensures the smooth operation of the shopping cart detection and verification system.

Step 1: Image Capture
Process: The camera mounted on the shopping cart captures image frames at a regular interval
Tools Used: Raspberry Pi Camera Module.
Goal: Continuously monitor the cart for changes in item presence.

Step 2: Item Detection (1st Model)
Process: The YOLO-based presence detection model processes the images to classify and detect the items.

Tools Used: YOLOv10 model trained on the custom dataset.

Output: Bounding boxes around detected items and classification results.

Step 3: Item Recognition (2nd Model)

Process: The output from the 1st model is cropped and then is processed by this model which recognizes various item in the cart.

Tools Used: YOLOv10 model trained on the custom dataset.

Output: Bounding Boxed on the recognized items with labels on them.

Step 4: Data Integration and Analysis

Process: Integrate detection results and weight data to make decisions.

Cross-validate the presence detection with weight verification.

Flag any inconsistencies for further user action.

Output: Combined detection results (item presence + weight validation).

Step 5: User Feedback and Alerts

Process: Display results to the user on the shopping cart screen.

Successful Detection: Add item in the user's cart and modify the quantity in the cart.

Alert the user with whenever the system generates an alert for camera block or weight mismatch.

Tools Used: Display module connected to Raspberry Pi.

Goal: Provide intuitive, real-time feedback to enhance user experience.

Step 6: Continuous Monitoring

Process: The system repeats the workflow in a loop until the shopping session ends.

Capture the next frame.

Re-analyze and update results.

Goal: Ensure consistent monitoring of items being added or removed.

5.2.2 Algorithms Used and Psuedocode

5.2.2.1 First Model: YOLOv10 for Item Detection

Architecture Summary

YOLO (You Only Look Once) is a single-stage object detection model. YOLOv10, the latest iteration, introduces several advancements for enhanced performance:

- **Convolutional Backbone**: Extracts hierarchical features from the input image.

- **Anchor Boxes**: Matches objects in the image to predefined bounding boxes, enabling precise localization.
- **Grid-Based Detection**: Divides the input image into a grid, with each cell predicting bounding boxes and associated class probabilities.
- **Non-Maximum Suppression (NMS)**: Filters overlapping bounding boxes to retain the most confident detections.

Why YOLOv10?

- **Real-Time Performance**: YOLO is designed for speed, making it ideal for continuous video feed analysis.
- **High Accuracy**: YOLOv10's improved architecture balances detection accuracy with minimal false positives.
- **Suitability for Customization**: The model can be fine-tuned for specific tasks like detecting various items in the cart.

Code Snippet

Fig shows the portion of the Flask app where YOLOv10 detects items presence

```
presence_results = presence_model(frame)[0]
presence_detections = sv.Detections.from_ultralytics(presence_results)


items_detected = []
bbox_array = presence_detections.xyxy
class_name_array = presence_detections.data.get("class_name", [])
cart_detected = "cart" in class_name_array

if cart_detected:
    no_cart_frames = 0
    camera = False
else:
    no_cart_frames += 1
    if no_cart_frames > ALERT_THRESHOLD:
        camera = True
```

Figure 12: Psuedocode-Item Presence Detection

5.2.2.2 Second Model: Custom-Trained YOLO for Item Classification

Training Process

- **Dataset**: The model was trained on a dataset containing labelled images of items commonly found in shopping carts.

- **Loss Function**:
    - **Localization Loss**: Ensures bounding box predictions are accurate.
    - **Confidence Loss**: Differentiates objects from the background.
    - **Classification Loss**: Assigns the correct class label to detected objects.
- **Optimization**: The Adam optimizer was used with a learning rate scheduler to improve convergence and avoid overfitting.

Why a Second Model?

- **Specialization**: While the first model detects items and the cart itself, the second model identifies specific item types, such as "Uncle Chips" or "Nabati Cheese Wafers".
- **Modularity**: Separating the models allows each to focus on a single task, improving accuracy and simplifying debugging.

5.2.2.1 Integration with Flask

Backend Workflow

The Flask application serves as the backend for processing webcam frames and updating the virtual shopping cart:

1. **Frame Processing**:
    - Frames are sent from the React frontend to the /process-image endpoint.
    - The image is base64-decoded and converted into an OpenCV format for processing.
2. **Item Presence Detection**:
    - The frame is passed through presence_model to detect items and the cart itself.
    - Bounding boxes of detected regions are extracted.
3. **Item Classification**:
    - Cropped regions from the bounding boxes are passed to recog_model for item classification.
    - The virtual_cart is updated based on the detected actions and items.

4. **Response**: The updated cart and detection results are returned to the frontend as a JSON response.

Pseudocode for Integration

1. **Initialization**:
    - Load YOLO models for presence detection and classification.

- Initialize a virtual cart (virtual_cart) as a dictionary.

2. **Process Image**:
    - Decode the image sent from the frontend.
    - Use the first model to detect items and the cart and extract bounding boxes.
    - Pass cropped regions to the second model for classification.
3. **Update Cart**:
    - Using the results of the second model update the virtual cart with the items that we receive.

4. **Return Results**:
    - Send the updated cart and detections to the frontend as a JSON response.

Figure 13: Psuedocode-Item Recognition and Update

```
cropped_frame = frame[y_min:y_max, x_min:x_max]

# Run the recognition model on the cropped frame
item_results = recog_model(cropped_frame)[0]
item_detections = sv.Detections.from_ultralytics(item_results)


for item_idx, item_bbox in enumerate(item_detections.xyxy):
    item_name = item_detections.data.get("class_name", ["unknown"])[item_idx]
    if item_name == "lays_green_20":
        item_name = "Lays American Style Cream & Onion - 20"
    elif item_name == "lays_green_50":
        item_name = "Lays American Style Cream & Onion - 50"

    # Update the virtual cart
    virtual_cart[item_name] = virtual_cart.get(item_name, 0) + 1

    # Log the detection
    items_detected.append({
        "name": item_name,
        "action": class_name,
        "confidence": float(presence_detections.confidence[largest_idx])
    })
```

5.3 Testing Process

This part contains the testing plan, the numerous test cases and their findings, as well as the measures used to ensure the project is successful.

5.3.1 Test Plan

Our analysis approach is carefully crafted to keep us in line with our objectives and performance standards. We thought that raising awareness of tiny, creative achievements could be the ideal strategy after talking about a lot of hints. We ensure consistent development and maintain the calibre of our work by segmenting the project into manageable chunks and thoroughly testing each step before proceeding.

5.3.2 Features to be tested

These are the following features that are being tested:

1. Putting item in
2. Taking item out
3. Detection of item
4. Total cart value display
5. If camera blocked then alert
6. Products Search
7. Bill sending on email
8. Promo code apply
9. Showing only those promo codes which satisfy the cart value
10. Camera stops taking feed when on checkout page

5.3.3 Test Strategy

To test each feature of our project we will be carrying out different testing strategies which would help us test our project in parts and then test it as a full unit. This helps to reduce errors and obtain maximum accuracy. We can check different features by performing different actions and match the obtained output with the expected one and decide whether the final product is reaching the accuracy level that we expect.

5.3.4 Testing Techniques

1. **Unit Testing**

- **Purpose**: The goal is to verify specific parts or modules, such as sensors, barcode scanners, and payment systems.

- **Examples**: Check that discounts are handled appropriately by the pricing computation module.

2. **Integration Testing**

- **Purpose:** Test the interaction between different parts together
- **Examples:**

- Ensure smooth communication between the scanner and the inventory database.
- Sync between the cart's sensors and its user interface.

3. **Functional Testing**

- **Purpose:** Ensure the system meets its functional requirements.
- **Examples:**
  - Check if items are added to the cart in the system when scanned.
  - Similarly check weather items are removed too.
  - Check payment gateway functionality for various payment methods.

5.3.5 Test Cases

Table 4 lists all the test cases which were checked for the system.

Table 4: Test Cases

S.No	Test Name	Test Description	Expected Result	Actual Result
1	Putting item in	Can items be added easily in the cart?	We should be able to add items easily.	Pass
2	Taking item out	Can items be removed easily from the cart?	We should be able to remove items easily.	Pass
3	Detection of item	Checking if the product added is recognized or not.	The product added is recognized.	Pass
4	Total cart value display	Is the cart showing the total value correctly after addition?	Shows the total cart value.	Pass
5	If camera blocked then alert	Does an alert appear when the camera is blocked?	If the camera is blocked, there should be an alert popup.	Pass
6	Product search	Is product information available when searched?	Shows the product info which is searched.	Pass
7	Bill sending on email	Does the bill reach the customer via email after purchase?	Bill should go to the customer via email after payment.	Pass
8	Promo code application	Can related promo codes be applied easily?	Promo code related to the purchase should be applied.	Pass
9	Showing only relevant promo codes	Are suggested promo codes based on the cart total value?	Display only promo codes that match the cart total value.	Pass
10	Camera stops taking feed on checkout	Does the camera stop once payment is completed?	Camera stops after moving to the checkout page.	Pass

5.3.6 Test Results

Our project satisfies all the test cases and fulfils all the features added in it still there is a scope of improvement and many other new features can be added according to the use cases of the customer and the staff. With next versions of the same product, we look forward to make improvements in the product and make it more efficient for daily use.

5.4 Results and Discussions

5.4.1 Overview of Model Performance

The performance of the two models used in this project—Presence Detection Model and Item Recognition Model—was evaluated based on various metrics, including Precision, Recall, and F1 Score.

5.4.1.1 Model Parameters

Presence Detection Model

Architecture: YOLOv10

Dataset: 1095 images (custom annotated)

Training	Testing	Validation	Total
999	66	30	1095

Table 5: Dataset Split for Presence Model

Number of Classes: 3 (cart, item-in, item-out)

Training Epochs: 64

Batch Size: 32

Optimizer: Adam

Learning Rate: 0.001

Item Recognition Model

Architecture: YOLOv10

Training Dataset: 1116 images (augmented)

Training	Testing	Validation	Total
1053	43	20	1116

Table 6: Dataset split for Recognition Model

Number of Classes: 6 (e.g., lays_green_20, lays_green_50)

Training Epochs: 64

Batch Size: 32

Optimizer: Adam

Learning Rate: 0.001

Model Performance Metrics

Table 7 summarizes the overall performance of the models

Metric	Presence Detection Model	Item Recognition Model
mAP	97.6	90.7
F1-Confidence Curve	94	88
Accuracy	85	85

Table 7: Model Metrics

5.4.2 Sales Insights Performance

Using the virtual cart data captured during the shopping process, we analyzed customer purchasing patterns. The sales data was grouped by individual orders to derive insights into total sales, most and least selling products, and average order value.

5.4.2.1 Sales Insights Visualization

The following graphs were generated based on the sales data:

- **Bar Chart:** Total sales per product
- **Pie Chart:** Revenue contribution by product
- **Box Plot:** Distribution of order totals

5.4.3 Discussion

Strengths

- The integration of the YOLOv10 architecture allowed for real-time object detection with high precision and recall.
- The modular design of the application facilitated the separation of detection and recognition tasks, improving scalability.
- Grouping sales data by Order_ID provided detailed insights into customer purchasing behavior.

Challenges

- Detecting items in crowded scenarios posed challenges due to occlusions or overlapping items in the cart.

- The dataset size, though sufficient for a proof of concept, may need to be expanded for detecting a larger variety of items.
- Items with similar packaging occasionally caused misclassification, requiring additional training data or augmentation techniques.

5.5 Validation of Objectives

The following objectives were approved and their completion has been described in the Table 9.

Table 8: Objective Status

S. No.	Objective	Status
1.	To create a hardware prototype with an integrated controller board with cameras and screen for interaction.	Successful
2.	To develop a machine learning model to detect and recognize various items placed in the shopping cart.	Successful
3.	To develop the user interaction software to accurately manage the addition or removal of items within the user's shopping cart and integrate it with the hardware.	Successful
4.	To analyze large volumes of data collected from smart shopping cart to provide various valuable insights to the retail owner.	Successful

CONCLUSION AND FUTURE DIRECTION

6.1 Conclusions

CartEase is a creative smart shopping cart system that links typical shopping with today's customer preferences. It significantly improves the shopping experience while enabling retailers to make smart choices based on data by using new technologies like self-scanning, integrated payment options, and real-time data analysis. CartEase takes away frustrations of no-checkout shopping, provides one-click product locating assistance, and includes powerful security features that increase customer satisfaction and reduce workload in the store. This project shows how ideas intended to meet the needs of the customers and technological improvements can significantly transform the retail sector to new standards for convenience and efficiency.

6.2 Environmental, Economic, and Societal Benefits

Benefits of CartEase smart shopping cart There are numerous environmental, economic, and societal benefits:

- **Environmental benefits:** By using digital payments and avoiding paper receipts, CartEase cuts down on paper use. It also removes issues of overstocking and understocking, which reduces waste from selling perishable or spoiled items.
- **Economic benefits:** It helps retailers benefit from data analysis for inventory management and targeted marketing, which means better store designs lead to higher sales with bigger profit margins. The checkout lines get shorter, efficiency increases for better use of resources, and it saves money. It creates new income sources by offering smart carts and analytics services as subscription products.
- **Societal Benefits:** Fewer frustrated and irritated customers are forced to wait in long lines at checkout counters, thus providing a more enjoyable and efficient shopping experience. Quick locating of products assists busy shoppers, seniors, and the disabled to shop comfortably and gain easier access to the store. Increased efficiency in the store translates to better customer satisfaction, loyalty, and a stronger retail market

6.3 Reflections

CartEase has been a very satisfying activity, showing the need to identify practical challenges in real life and find solutions based on innovative ideas. Technical competence, collaboration, and a user-centered approach blend well in the project that displays the importance of user needs against viable technical feasibility. The task in dealing with object detection capability integration and simple payment handling systems has been the ground for some valuable learning exercises. We now understand the crucial role of meaningful solutions not in technical skills but also an understanding of user needs and the more general business context.

6.4 Future Work

Even though the current version of CartEase offers a strong and groundbreaking shopping experience, it still has opportunities for several improvements:

- **AI-Driven Personalization:** Adding AI techniques to offer more personalized suggestions based on customer purchase history and preferences.
- **Mobile App Integration:** Connecting the system with a mobile app, allowing customers to see real-time cart updates, deals, and manage their shopping lists.
- **Sustainability Features:** Looking into Renewable Energy Sources such as charging smart carts using solar power to reduce energy consumption.
- **Multi-Language Support:** Including multiple language support options that help to reach out to various segments, thereby increasing access to more global markets.
- **Advanced Analytics for Retailers:** The dashboards that are sophisticated analytics with the capability of providing forecasting will allow retailers to enhance their management of inventory, promotions, and store formats.

The future of CartEase is built on its ability to grow and adapt, and therefore smarter and more efficient retail environments will emerge around the world.

PROJECT METRICS

7.1 Challenges Faced

Challenges In creating CartEase, several challenges were identified:

- **Technological Implementation:** Using YOLO-based object detection necessitated considerable testing and calibration to ensure that the products were correctly identified.
- **User Experience Design:** This was challenging and complex to balance feature complexity with the ease of the interface
- **Hardware Selection:** Selection of hardware components that would be cost-effective yet reliable enough for real-time scanning and data processing.

  Each problem became an opportunity to learn, which forced the team to find solutions and improve the system.

7.2 Relevant Subjects

The subjects that were employed in the making of the project have been listed in Table 9.

Subject Code	**Subject Name**	**Description**
UML501	Machine Learning	In developing the model required for detecting and recognizing the items in the cart.
UTA003	Computer Programming	In writing logic for the backend server
UCS414	Computer Networks	In sending requests to the server on different ports.
UCS503	Software Engineering	In recognizing the various stages of the Project and the report.

Table 9: Relevant Subjects

7.3 Interdisciplinary Knowledge Sharing

The success of CartEase is a product of the collaboration of departments. Technical, business, and design were all involved in the conception of the product that was innovatively developed. All this would happen through the collaboration of the team members to merge the technical strategies with the business plans into one final product that was not only effective but also marketable. Their knowledge sharing fosters creativity, problem solving, and skill development.

7.4 Peer Assessment Matrix

		Evaluation of				
		Sukhmani Arora	Aadi Jain	Akshat Gupta	Amogh Rew	Samarjeet Singh Gandhi
Evaluation By	Sukhmani Arora	5	5	5	5	5
	Aadi Jain	5	5	5	5	5
	Akshat Gupta	5	5	5	5	5
	Amogh Rew	2	2	2	5	5
	Samarjeet Singh Gandhi	3	3	3	5	5

7.5 Role Playing and Work Schedule

With the optimum use of the resources available to us, this represents the contribution of individual members of the team into this project in order to complete the proposed project in time. Roles that different members of the team performed with coordination with other peers and our mentor are:

- Sukhmani Arora: Setting Up Weight Sensor, Sending Weight Sensor Data on Blynk Server
- Aadi Jain: Dataset Image Annotation
- Akshat Gupta: Setting Up Weight Sensor, Sending Weight Sensor Data on Blynk Server
- Amogh Rew: Backend, ML Model training, Dataset Annotation and Creation, Web Server Debugging, Raspberry Pi Setup with Hardware Interfaces.
- Samarjeet Singh Gandhi: Frontend, Mail Server, Dataset Annotation, Web Server Debugging, Raspberry Pi Setup with Interfaces.

7.6 Student Outcomes Description and Performance Indicators

Table 10: Student Outcome Description

Student Outcomes	**Student Outcomes Description**	**Outcome**
1.1	Ability to identify and formulate problems related to computational domain	Identifying a problem and applying computational knowledge to solve it
2.1	Design computing system(s) to address needs in different problem domains and build prototypes, simulations, necessary, that meet design and implementation specifications.	Designing a hardware prototype and a software user interface to satisfy the problem statement.
5.1	Participate in the development and selection of	Discussed and brainstormed various implementations to achieve the

	ideas to meet established objective and goals.	objectives.
6.1	Ability to perform experimentations and further analyze the obtained results	Implemented and tested various logic for item detection and recognition.
6.2	Ability to analyze and interpret data, make necessary judgement(s) and draw conclusion(s).	Analyzed model parameters to tune and train it further to optimize performance.
7.1	Able to explore and utilize resources to enhance self-learning.	Explored various technologies and gained insights on how best to implement them.

7.7 Brief Analytical Assessment

Q1. What sources of information did your team explore to arrive at the list of possible Project Problems?

Ans: The group was aware of the understanding of the Capstone requirement and some of the problems that needed to be explored. Our foremost motivation was our own real-life experience that we faces and observed a gap that could be filled. Some parts of the internet also played a part in arriving at the list of possible project problems.

Q2. What analytical, computational and/or experimental methods did your project team use to obtain solutions to the problems in the project?

Ans: Our project consists of Object Detection, Object Recognition, Weight Sensor integration and other hardware integration. We used deep learning and machine learning techniques for object detection and recognition and Blynk software

Q3. Did the project demand demonstration of knowledge of fundamentals, scientific and/or engineering principles? If yes, how did you apply?

Ans: We used quite a lot of engineering subjects such as Machine Learning, Computer Engineering, Web Development, Software Engineering etc. Software Engineering was used for the research, formulation, and documentation of the solution.

Q4. What resources did you use to learn new materials not taught in class for the course of the project?

Ans: We took online tutorials and online courses. Moreover we read through various blogs, articles, research papers and guides to learn the new concepts.

REFERENCES

[1] S. R. Subudhi and R. N. Ponnalagu, "An Intelligent Shopping Cart with Automatic Product Detection and Secure Payment System," *IEEE 16th India Council International Conference (INDICON),* 2019.

[2] P. Mounica, K. Natarajan and R. Shanmugasundaram, "Intelligent Shopping Cart using IoT Technology," *3rd International Conference on Communication, Computing and Industry 4.0 (C2I4),* 2022.

[3] N. Ragesh, B. Giridhar, D. Lingeshwaran, P. Siddharth and K. P. Peeyush, "Deep learning based automated billing cart," *International conference on communication and signal processing,* 2019.

[4] N. Shekokar, A. Kasat, S. Jain, P. Naringrekar and M. Shah, "An innovative approach towards shopping using Deep Learning and Computer Vision," *Third International Conference on Smart Systems and Inventive Technology (ICSSIT),* 2020.

[5] B. A. Padma, A. Aravindakshan and A. Prakash, "Automation of shopping carts using technology," *IEEE 5th International Conference for Convergence in Technology (I2CT),* 2019.

[6] D. Belibov and D. S. Tudose, "Smart Shopping Cart," *18th RoEduNet Conference: Networking in Education and Research (RoEduNet),* 2019.

[7] R. Li, "IoT applications on secure smart shopping system," *IEEE Internet of Things Journal 4.6,* 2017.

[8] A. Yewatkar, "Smart cart with automatic billing , product information , product recommendation using RFID and Zigbee with anti-theft," *Procedia Computer Science 79,* pp. 793-800, 2016.

[9] M. Shahroz, "IoT - based smart shopping cart using radio frequency identification," *IEEE Access 8,* 2020.

[10] A. P. James and Y. Berdaliyev, "RFID-Cloud smart cart system," *International Conference on Advances in Computing , Communications and Informatics (ICACCI),* 2016.

[11] S. Kowshika, "IoT based smart shopping trolley with mobile cart applications," *7th International Conference on Advanced Computing and Communication Systems (ICACCS),* 2021.

[12] H. H. Chiang, "Development of smart shopping carts with customer-oriented service," *International Conference on System Science and Engineering (ICSSE),* 2016.

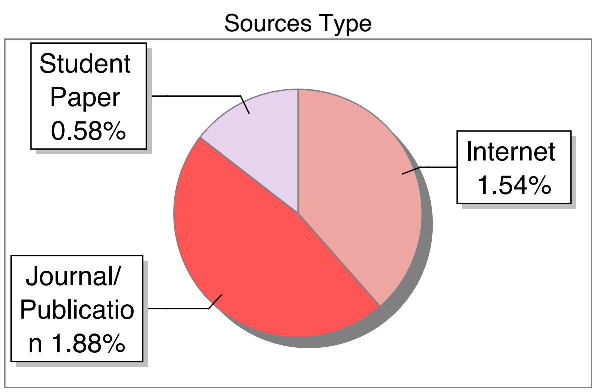
The Report is Generated by DrillBit Plagiarism Detection Software

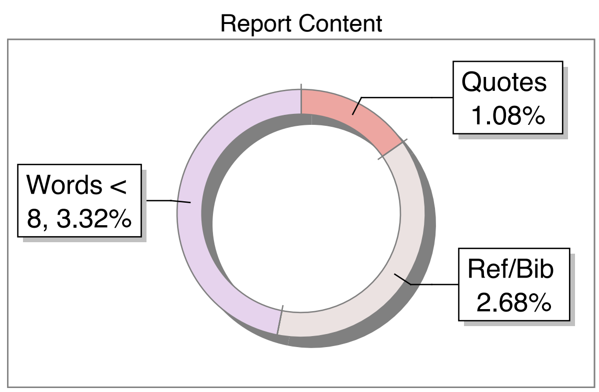
Submission Information

Author Name	Amogh
Title	CartEase
Paper/Submission ID	2803959
Submitted by	tarunpreet@thapar.edu
Submission Date	2024-12-18 19:44:23
Total Pages, Total Words	53, 10540
Document type	Others

Result Information

Similarity **4 %**





Exclude Information

Quotes	Not Excluded
References/Bibliography	Excluded
Source: Excluded < 8 Words	Excluded
Excluded Source	**0 %**
Excluded Phrases	Not Excluded

Database Selection

Language	English
Student Papers	Yes
Journals & publishers	Yes
Internet or Web	Yes
Institution Repository	Yes

A Unique QR Code use to View/Download/Share Pdf File

DrillBit

DrillBit Similarity Report

4	24	A	A-Satisfactory (0-10%) B-Upgrade (11-40%) C-Poor (41-60%) D-Unacceptable (61-100%)
SIMILARITY %	MATCHED SOURCES	GRADE	

LOCATION	MATCHED DOMAIN	%	SOURCE TYPE
1	REPOSITORY - Submitted to Exam section VTU on 2024-07-31 15-26 968365	1	Student Paper
2	en.wikipedia.org	1	Internet Data
3	www.readbag.com	<1	Internet Data
5	springeropen.com	<1	Internet Data
7	Climatological characteristics of fronts in the western North Pacific by Utsumi-2014	<1	Publication
9	www.academia.edu	<1	Internet Data
10	journals.indexcopernicus.com	<1	Publication
11	in.mathworks.com	<1	Internet Data
13	Impacts of Internet of Things on Supply Chains A, by Mostafa, Noha Hamd- 2019	<1	Publication
14	jurnal.isbi.ac.id	<1	Internet Data
15	repository.up.ac.za	<1	Publication
16	Deep Learning for Real-Time Capable Object Detection and Localization on Mobile by Particke-2017	<1	Publication