A

PROJECT PAHSE-1

REPORT

On

Self-Checkout Smart Store System

Submitted in partial fulfillment of the requirements for the degree of

Bachelor of Technology in **Information Technology**

By

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Under the guidance

of

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CERTIFICATE

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Students of Information Technology, bearing has successfully completed project phase-1 report on

Self-Checkout Smart Store System

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Date:
Place: SVKM's IOT, Dhule

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Name and Sign with Date	Name and Sign with Date
Examiner 1	Examiner 2

DECLARATION

We declare that this written submission represents ideas in our own words and whereother's ideas or words have been included, we have adequately cited and referenced the original sources. We also declare that we have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in our submission.We understand that any violation of the above will cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or fromwhom proper permission has not been taken when needed.

Signatures

Mr. Vineet Vipul Chopade -

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Mr. Piyush Kumar Agrawal -

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ACKNOWLEDGEMENT

We have immense pleasure in expressing our interest and deepest sense of gratitude towards our project guide **Prof. Rubi Mandal** for the assistance, valuableguidance, and co-operation in carrying out this project successfully. It is a privilege for us to havebeen associated with our Project Guide, during our Project Phase 1 work. We have greatly benefited from his/her valuable suggestions and ideas. It is with great pleasure that we express our deep sense of gratitude to him/her for his/her valuable guidance, constant encouragement, and patience throughout this work. We express our gratitude and are thankful to all people who have contributed in their way in making this final year project phase 1 success. Particularly we want to thank **Prof. Rubi Mandal**, Project Coordinator for our department for making this process seamless for us and arranging everything so perfectly. I take this opportunity to thank allthe classmates for their company during the course work and for the useful discussion I had with them. We take this opportunity to express our heartfelt gratitude towards the Department of Information Technology of Shri Vile Parle Kelavani Mandal's Institute of Technology, Dhule Head of the Department, **Dr. Bhushan Chaudhari** and **Dr. Nilesh Salunkhe,** Principal of Shri Vile Parle Kelavani Mandal's Institute of Technology, Dhule, that gave us an opportunity for the presentation of our project phase 1 in the esteemed organization and for providing the required facilities in completing this project. We are greatly thankful to our parents, friends and other faculty members for their motivation, guidance and help whenever needed.

ABSTRACT

The self-checkout store system is a retail solution aimed at revolutionizing the traditional shopping experience. This innovative concept leverages advanced technology and automation to provide customers with a seamless and efficient checkout process. The project aims to address common challenges faced by both customers and retailers, such as long queues, cashier errors, and inventory management inefficiencies. The self-checkout store utilizes computer vision, machine learning and Digital Payment System to enable customers to shop freely without the need for traditional checkout counters or cashier assistance. Upon entering the store, customers can use a smartphone app to check in the store by scanning a QR code generated by the application and add items in their shopping cart. The system automatically detects objects within an image or video frame and links each customer to the items they add to their cart. When the item is placed in the cart the total cost is calculated, providing real-time information on the purchased items. By adopting the self-checkout store model, retailers can reduce labor costs, minimize checkout waiting times, and improve customer satisfaction. The project aims to demonstrate the feasibility and advantages of this innovative retail solution through a prototype implementation in a real-world retail environment. As the retail industry continues to evolve, this self-checkout store system presents a forward- thinking approach that has the potential to shape the future of retail shopping.

Keywords: computer vision, machine learning.

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1. INTRODUCTION

1.1. Introduction of Project

The self-checkout store system is a retail solution aimed at revolutionizing the traditional shopping experience. This innovative concept leverages advanced technology and automation to provide customers with a seamless and efficient checkout process. The self-checkout store utilizes computer vision, machine learning, Sensor technology, and Digital Payment System to enable customers to shop freely without the need for traditional checkout counters or cashier assistance. The self-checkout store system is a cutting-edge retail solution designed to transform the conventional shopping experience. Through the integration of sophisticated technologies such as computer vision, machine learning, sensor technology, and digital payment systems, this innovative concept eliminates the need for traditional checkout counters and cashier assistance. Customers can now shop freely, navigating the store without the constraints of conventional checkout processes. Computer vision enables seamless item recognition, while machine learning refines the system's efficiency over time. Sensors facilitate a hands-free experience, detecting and tallying items in the customer's cart. The digital payment system adds convenience, allowing for swift and secure transactions. This self-checkout approach not only enhances customer autonomy but also streamlines the overall shopping journey, making it more time-efficient and reducing wait times. The store's reliance on automation and advanced technologies reflects a shift towards a more modern and customer-centric retail landscape.

1.2. Motivation Behind Project

The motivation to address and reduce queues in retail stores stems from the profound impact that long waiting times have on customer behavior and business outcomes. An alarming 86% of customers actively avoid stores with lengthy queues, leading to immediate losses and diminished potential for repeat business. With the average person spending a considerable amount of time—specifically, one year, two weeks, and a day—waiting in shop queues throughout their lives, there is a growing impatience among modern consumers. The tipping point for dissuading shoppers is identified as seven people in a queue, emphasizing the critical importance of managing queue length. Furthermore, after just 9 minutes, or as little as 6 minutes according to some research, shoppers are highly likely to abandon the queue, underscoring the need for swift and efficient checkout processes. The impact is not limited to immediate purchases; 70% of customers are less likely to return to a store if they experience long waiting times on just one occasion, highlighting the lasting negative impression of a single poor queueing experience. With the average shopping trip including 20 minutes of queuing time, the motivation to streamline the checkout process is clear—by leveraging technology and efficient systems, retailers can enhance overall satisfaction, maintain a positive brand image, and ultimately increase sales.

1.3. Aim and Objectives of the work.

The project is designed to tackle prevalent challenges experienced by both customers and retailers, including issues such as extended queues, cashier errors, and inefficient inventory management. Its primary goal is to offer customers a seamless and efficient checkout process. The outlined project objectives aim to achieve several key outcomes. Firstly, retailers stand to benefit from a reduction in labor costs, a critical factor in optimizing operational expenses. Secondly, the project seeks to minimize checkout waiting time, recognizing the impatience of modern consumers and their avoidance of stores with prolonged queues. Lastly, by addressing common pain points in the retail experience, the project aims to enhance overall customer satisfaction, contributing to a positive brand image and fostering customer loyalty. Collectively, these objectives align with the overarching goal of creating a more efficient and satisfying shopping experience for both customers and retailers alike.

- **Labor Cost Reduction:**
  Streamline the checkout process to reduce reliance on human cashiers, leading to a significant reduction in labor costs for the retailer.

- **Minimization of Checkout Waiting Time:**
  Implement a self-checkout system that ensures swift processing of transactions, minimizing customer wait times and addressing the impatience associated with prolonged queues.

- **Error Reduction in Checkout Process:**
  Eliminate cashier errors through the implementation of automated systems, enhancing transaction accuracy and reducing the likelihood of billing discrepancies.

- **Efficient Inventory Management:**
  Integrate the self-checkout system with the inventory management system to ensure real-time tracking of product quantities, reducing instances of stockouts and overstock situations.

- **Enhanced Customer Satisfaction:**

Focus on improving the overall customer experience by providing a seamless and efficient checkout process, leading to increased satisfaction among shoppers.

- **Adaptability and Scalability:**

  Design the self-checkout system to be adaptable to evolving retail needs and scalable to accommodate future growth, technological advancements, and additional features. By addressing these objectives, the project aims to create a win-win situation for both customers and retailers, fostering a more efficient and satisfying shopping experience.

1.4. Scope of the topic

The scope of this project encompasses a comprehensive approach to address key challenges within the retail sector, targeting issues such as extended queues, cashier errors, and inventory management inefficiencies. By prioritizing the enhancement of the checkout process, the project aims to contribute significantly to the operational efficiency of retailers. The scope extends to the reduction of labor costs, a critical aspect in optimizing resources for businesses. Additionally, the project strives to minimize checkout waiting times, recognizing the pivotal role time plays in shaping consumer preferences. By focusing on these objectives, the project aspires to create a retail environment that not only streamlines operations but also markedly improves customer satisfaction, fostering a positive and enduring relationship between consumers and retailers.

2. LITERATURE SURVEY

2.1. Literature

The implementation and optimization of self-checkout systems have become pivotal in the modern retail landscape, offering convenience and efficiency to both retailers and consumers. This discussion focuses on three significant papers exploring various aspects of self-checkout technologies, namely "Self-Checkout System Using RFID (Radio Frequency Identification) Technology: A Survey," "Shop and Go: An Innovative Approach Towards Shopping Using Deep Learning and Computer Vision," and "Just Walk-Out Technology and Its Challenges: A Case of Amazon Go. “The "Self-Checkout System Using RFID Technology" paper delves into the challenges and parameters associated with implementing RFID technology in self-checkout systems.[7][10] It addresses issues such as tag accuracy, interference, and the overall cost of implementation. The work primarily revolves around overseeing the integration and optimization of RFID self-checkout systems. This involves ensuring the accuracy of RFID readers and antennas, managing the cost of implementation, and implementing robust security measures to safeguard user privacy through RFID tags. Collaborative efforts with cross-functional teams play a crucial role in achieving seamless integration, accuracy, and user-friendly experiences.

The "Shop and Go" paper explores an innovative approach to self-checkout by incorporating Deep Learning and Computer Vision.[5] Key issues highlighted include user privacy concerns, adoption rates, and overall user experience. The work encompasses overseeing the deployment of the "Shop and Go" autonomous shopping system. This includes integrating advanced security protocols and surveillance systems, addressing user privacy concerns, and optimizing the system's performance through high-performance computing and efficient algorithms. The goal is to ensure the system's accuracy, security, and user privacy while maintaining compatibility with existing retail infrastructure.[9] The "Just Walk-Out Technology and Its Challenges" paper focuses on Amazon Go's revolutionary cashier-less shopping experience. It addresses challenges related to customer education and trust, loss prevention, and the user experience learning curve. The work involves overseeing the deployment of Amazon Go's "Just Walk-Out" technology, ensuring sensor accuracy through advanced technologies like cameras and weight sensors. Additionally, robust data privacy and security measures are implemented, including secure data storage systems, encryption techniques, and access controls. The aim is to protect customer information from unauthorized access and data breaches while providing a seamless and efficient cashier-less shopping experience. In conclusion, these papers collectively underscore the multifaceted nature of self-checkout systems, emphasizing the importance of accuracy, security, user privacy, and seamless integration with existing retail infrastructure. The collaborative efforts and strategic deployment of advanced technologies are pivotal in realizing the full potential of self-checkout systems and reshaping the future of retail.[3][5]

Reference No. /Paper Title	Issues Found	Parameters / Tools Used	Work Description
Self-Checkout System Using RFID (Radio Frequency Identification) Technology: A Survey	Tag Accuracy and Interference, Cost of Implementation	Read Accuracy/ RFID Readers and Antennas Security Measures/ RFID Tags	Oversee the integration and optimization of RFID self-checkout systems, ensuring accuracy, security, and a user-friendly experience while managing costs and privacy compliance. Collaborate with teams for seamless implementation.
Shop and Go: An innovative approach towards shopping using Deep Learning and Computer	User Privacy Concerns, User Adoption and Experience	Security Measures/ Advanced security protocols and surveillance systems (e.g., CCTV) to prevent theft, and secure payment processing. Technological Optimization/ High-performance computing systems (e.g., GPUs, TPUs) and efficient algorithms for real-time processing (e.g., Apache Kafka).	Responsible for deploying the "Shop and Go" autonomous shopping system, overseeing the integration of Deep Learning and Computer Vision tools, optimizing accuracy, security, and user privacy, and ensuring seamless compatibility with existing retail infrastructure.

Just Walk-Out Technology and its Challenges: A case of Amazon Go	Customer Education and Trust, Loss Prevention, User Experience and Learning Curve	Sensor Accuracy/ Advanced sensor technologies, including cameras and weight sensors, for precise and reliable tracking of customer movements and product interactions. Data Privacy and Security Measures/ Secure data storage systems, encryption techniques, and access controls to protect customer information from unauthorized access or data breaches.	Oversee the deployment of Amazon Go's "Just Walk-Out" technology, managing integration, scalability, security, and user experience enhancements to ensure a seamless and efficient cashier-less shopping experience.

3. PROBLEM STATEMENT

3.1. Problem statement

The traditional checkout processes are plagued by persistent challenges such as extensive queues, cashier errors, and a lack of efficiency. These issues not only contribute to customer dissatisfaction but also result in increased operational costs for businesses. To address these pressing concerns, the project aims to develop a revolutionary Self-Checkout Store System that leverages cutting-edge technologies, including computer vision, machine learning, and a Digital Payment System.

3.2. Project Requirement Specification

A. ESP 32: -

The ESP32 camera in a Self-Checkout Smart System can be employed for object recognition, enabling accurate tracking of items in the cart, user authentication through facial recognition, and real-time monitoring for security and assistance, enhancing overall efficiency and user experience.

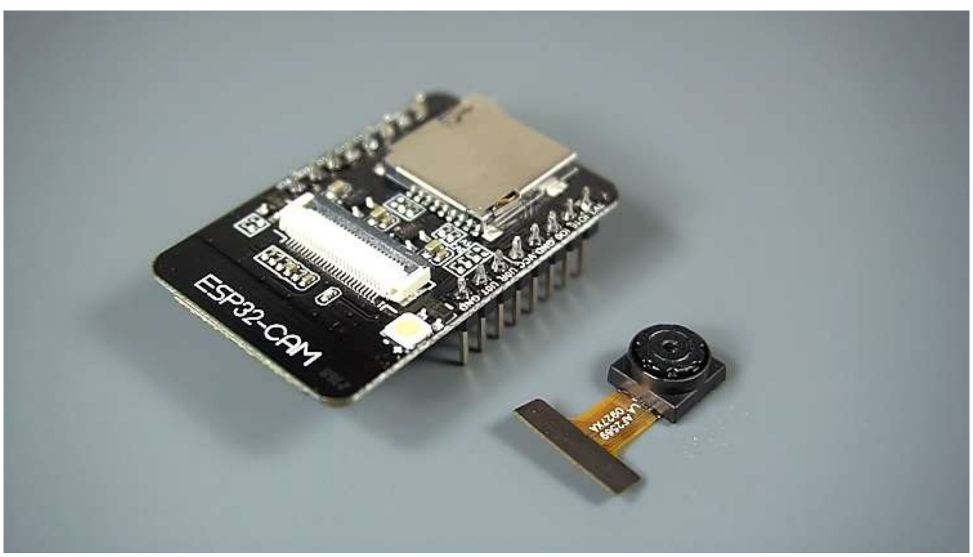


Fig 3.1 ESP-32 (Camera Module for Object Detection)

B. Arduino Uno

The Arduino Uno plays a pivotal role in several key functions. Firstly, it facilitates seamless sensor integration to detect and track items in the shopping cart, ensuring accurate and efficient self-checkout processes. The Arduino Uno also serves as the brain behind the user interface, allowing customers to interact with the system through buttons or a touchscreen, enabling smooth item scanning and payment procedures. Additionally, the Arduino Uno contributes to transaction processing, interfacing with a Digital Payment System to ensure secure and reliable financial transactions during the self-checkout experience. Furthermore, the versatility of Arduino Uno extends to RFID integration, providing enhanced item identification and tracking capabilities, ultimately streamlining the entire checkout process for improved efficiency and customer satisfaction.

Fig 3.2 Arduino Uno (Connections with ESP-32)

4. PROPOSED SYSTEM

4.1. Proposed System Architecture

The proposed self-checkout system features a streamlined workflow encompassing customer identification, item tracking, and convenient payment processes. The system architecture begins with customers scanning a QR code on the cart, linking it to their account. This initial step establishes a unique identifier for the cart, ensuring a personalized shopping experience. Subsequently, as customers add items to their physical cart, the system mirrors this in real-time by updating their virtual cart, creating a seamless connection between the physical and virtual shopping experiences.

To enhance security and personalize transactions, customers are required to scan their cart's QR code, linking it to their account. This linkage ensures that the system accurately associates the selected items with the corresponding customer account. This approach not only simplifies the checkout process but also allows for personalized recommendations or promotions based on the customer's purchase history.

The culmination of the shopping journey involves the automatic generation of a bill, reflecting the items in both the physical and virtual charts. The generated bill is then presented to the customer, who can conveniently pay through a mobile application. This payment method leverages the integration of a secure and user-friendly mobile payment system, ensuring a smooth and efficient transaction experience. Overall, the system architecture integrates seamlessly, providing customers with a technologically advanced, personalized, and efficient self-checkout experience.

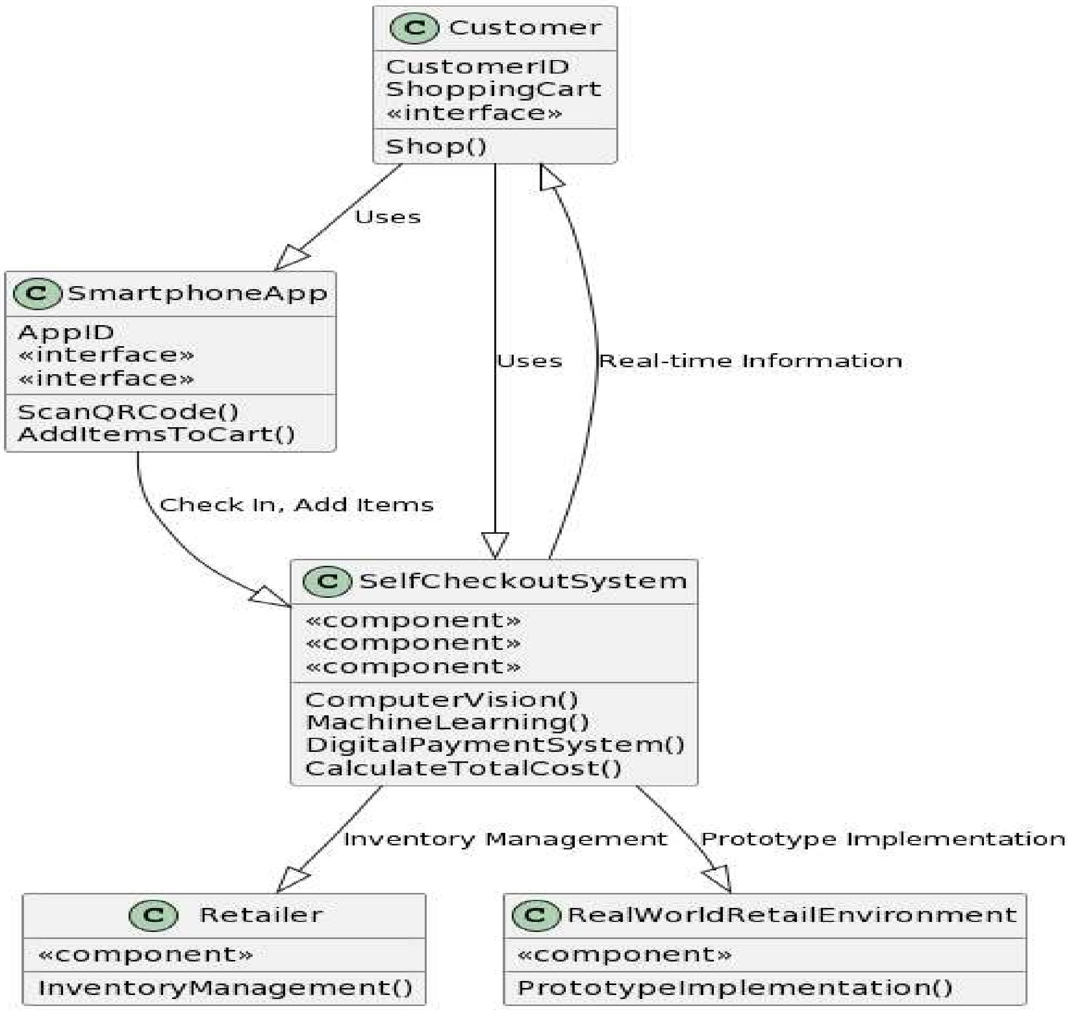


Fig 4.1. Proposed System Architecture

4.2. Proposed Methodology

Designing a smart store system involves careful planning and consideration of various aspects, including technology integration, user experience, and operational efficiency. Here's a proposed methodology for developing a smart store system:

Define Objectives and Requirements: Clearly outline the objectives of the smart store system. Identify specific requirements, such as seamless checkout, inventory management, and customer analytics.

Technology Selection: Choose appropriate technologies based on the identified requirements. This may include:

- Computer Vision for item recognition.
- Machine Learning for system optimization and personalization.
- Sensor technology for tracking inventory and customer movements.
- Digital Payment Systems for secure and efficient transactions.

System Architecture: Design a scalable and flexible system architecture that accommodates current and future technological advancements. Consider cloud-based solutions for storage, processing, and scalability.

User Experience (UX) Design: Prioritize a user-centric design to ensure a positive customer experience. Create an intuitive and easy-to-use interface for both in-store customers and store staff. Implement feedback mechanisms for continuous improvement.

Integration with Existing Systems: Integrate the smart store system with existing retail systems, such as inventory management and customer relationship management (CRM) software. Ensure compatibility with various hardware and software components.

Testing and Quality Assurance: Conduct thorough testing of the smart store system in simulated and real-world environments. Address any issues related to performance, reliability, and user experience.

Training and Education: Provide comprehensive training for store staff to ensure they are familiar with the smart store system. Educate customers on how to use the system for a smooth shopping experience.

Continuous Improvement: Implement a feedback loop for continuous improvement, considering customer feedback, technological advancements, and changes in retail trends.

5. HIGH LEVEL DESIGN OF PROJECT

5.1. Use-case Diagram

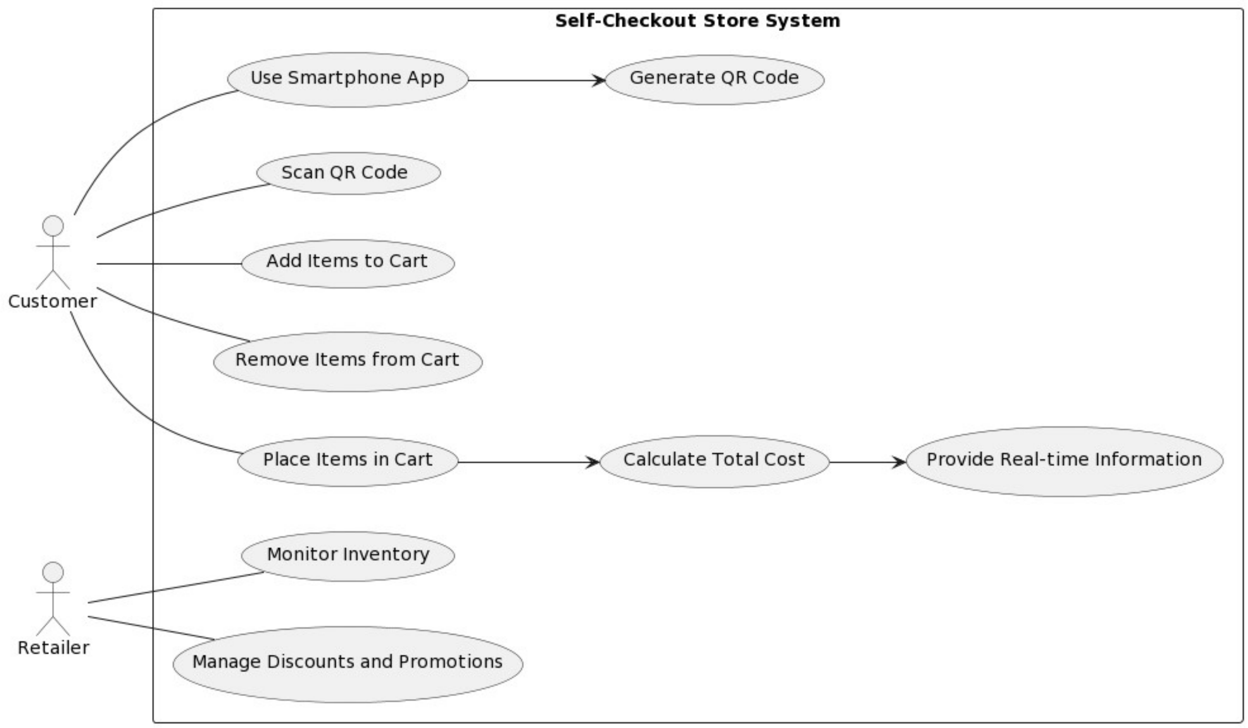


Fig. 5.1. Use-case Diagram

In this diagram:

- **Actors:**
  - **Customer (C):** Interacts with the system using the smartphone app, scans QR codes, adds/removes items from the cart, and checks out.
  - **Retailer (R):** Monitors inventory, manages discounts, and promotions.
- **Use Cases:**
  - **Check-In:** Represents the process of the customer checking into the store using the smartphone app and scanning the QR code.
  - **Shopping:** Involves the customer adding or removing items from the shopping cart.
  - **Checkout:** Encompasses the process of placing items in the cart, calculating the total cost, and providing real-time information.

- **Relationships:**
    - Customers interact with the system during the Check-In, Shopping, and Checkout processes.
    - The Retailer interacts with the system to monitor inventory and manage discounts/promotions.

5.2. Class Diagram

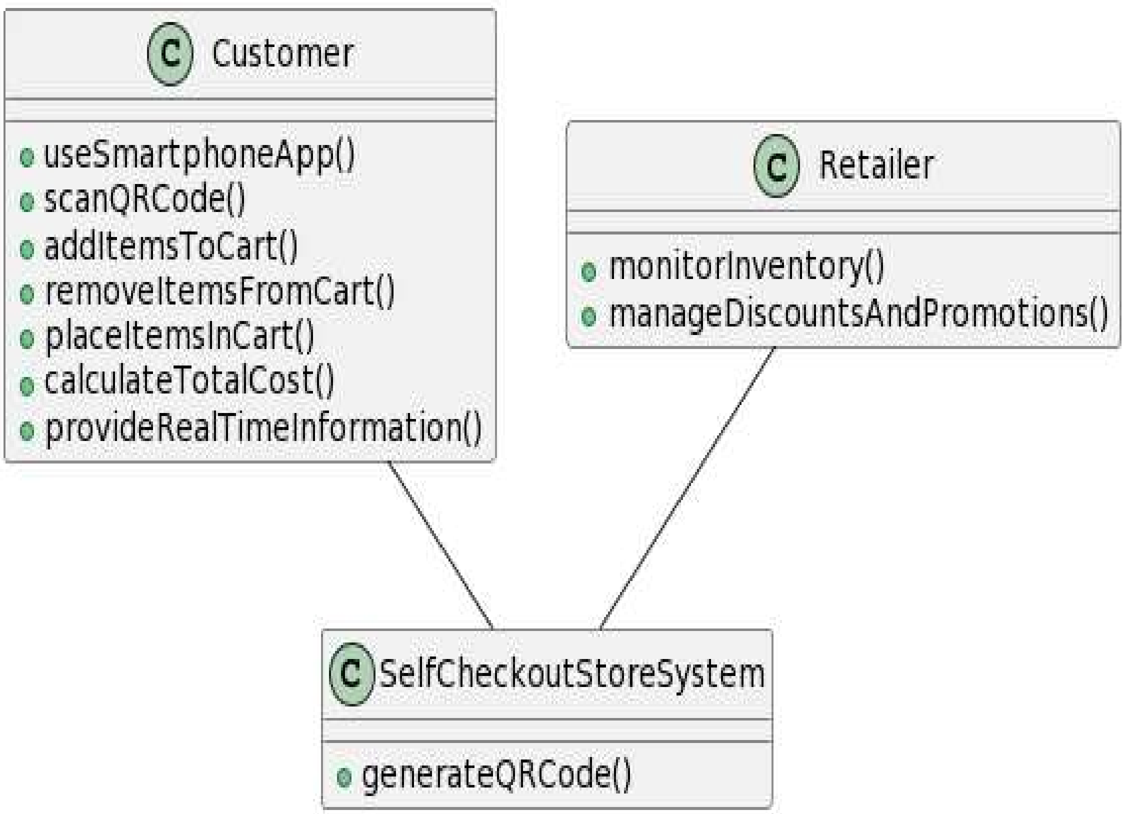


Fig. 5.2. Class Diagram

In this class diagram:

- **Customer** has methods representing actions such as using the smartphone app, scanning a QR code, adding/removing/placing items in the cart, calculating the total cost, and providing real-time information.

- **Retailer**s have methods for monitoring inventory and managing discounts and promotions.
- **Self-Checkout Store System** is a class that generates QR codes and is associated with both **Customer** and **Retailer**.

5.3. Sequence Diagram

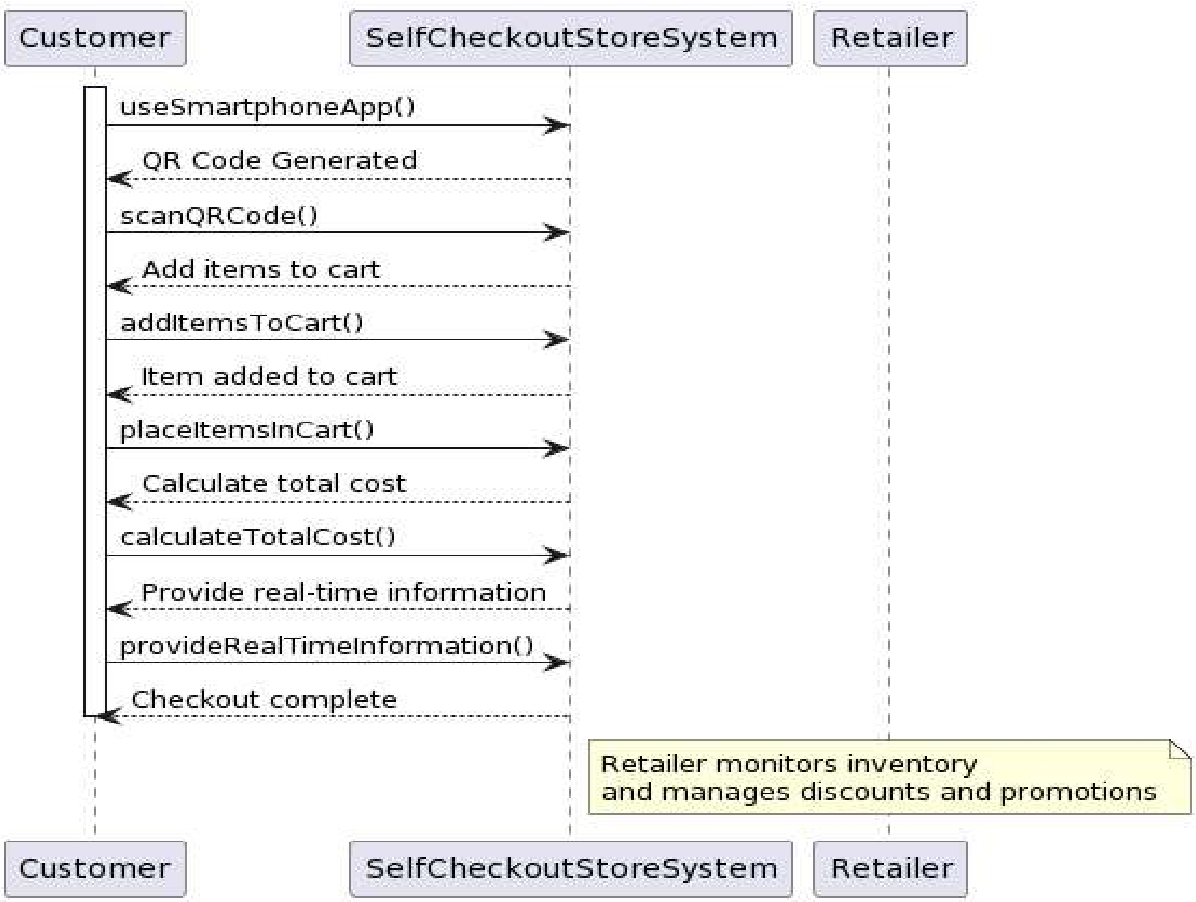


Fig. 5.3. Sequence Diagram

In this sequence diagram:

- **Customer**, **Self-Checkout Store System**, and **Retailer** are the participants.
- Activation bars represent the lifetimes of the objects during interactions.
- Arrows represent the flow of messages between the objects.

5.4. State Diagram

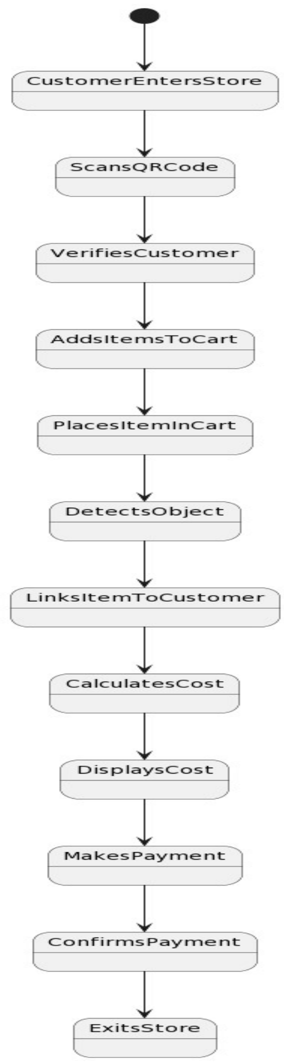


Fig. 5.4. State Diagram

In this state diagram:

- The system starts in the **Check-in** state.

- The **Check-in** state transitions to the **Idle** state when the customer initially checks in.
- From the **Idle** state, the system can transition to the **Shopping** state when the customer scans the QR code.
- In the **Shopping** state, the customer can add or remove items from the cart, and when ready, transition to the **Checkout** state to complete the purchase.
- In the **Checkout** state, the system calculates the total cost and provides real-time information. The customer can continue shopping or go back to the **Idle** state by scanning the QR code.

6. FEASIBILLITY STUDY

6.1. Introduction to Feasibility Study

The feasibility study for the proposed project addressing challenges in the retail sector, such as long queues, cashier errors, and inventory management inefficiencies, is a critical examination of the project's viability and potential success. This study aims to assess the practicality and feasibility of implementing the outlined objectives. As the retail landscape evolves, with customer expectations and technological capabilities advancing, it becomes imperative for retailers to adapt and enhance their operations. This feasibility study will delve into the anticipated benefits, including the reduction of labour costs, streamlined checkout processes, and improved customer satisfaction. By analysing the economic, technical, and operational aspects, this study seeks to provide a comprehensive understanding of the project's viability, laying the foundation for informed decision-making by stakeholders involved in the retail sector.

6.2. Economic Feasibility

The economic feasibility analysis of the proposed retail enhancement project is integral to assessing its viability and financial impact. By calculating the cost-benefit ratio, determining the return on investment, and scrutinizing operational cost reductions, this analysis aims to provide a comprehensive overview of the project's economic viability. Additionally, it explores opportunities for market expansion, considering potential increases in customer traffic and sales volume resulting from improved customer satisfaction and streamlined operations. The assessment will also delve into the upfront costs of implementing new technologies and training programs, with a sensitivity analysis addressing variables that could influence financial outcomes. In essence, this economic feasibility study is crucial for stakeholders, offering insights that guide decision-making and ensure the project aligns with financial objectives and market realities.

6.3. Technical Feasibility

The technical feasibility analysis for the proposed retail enhancement project is pivotal in determining the project's compatibility with existing systems and its ability to leverage advanced technologies effectively. The assessment begins by scrutinizing the compatibility of proposed systems with the current technological infrastructure of the retail environment, ensuring a seamless integration process that avoids disruptions. Scalability considerations are paramount, evaluating the capacity of the proposed solutions to handle potential future growth and increased transaction volumes. Equally critical is the examination of data security and privacy measures to ensure compliance with regulations and safeguard customer information.

Additionally, the analysis delves into the training requirements for staff to proficiently operate and manage the new systems, emphasizing the need for comprehensive training programs to facilitate a smooth transition. Reliability and maintenance protocols are established to address any technical issues promptly, ensuring minimal downtime and continuous operations. Interoperability, a key factor, is examined to confirm that various systems, including point-of-sale and inventory management, can seamlessly communicate and share data for a cohesive retail operation. In essence, the technical feasibility analysis focuses on practical implementation, aiming to harmonize technology with the existing retail environment and contribute to the seamless execution of the proposed enhancements.

6.4. Behavioral Feasibility

The behavioral feasibility analysis for the proposed retail enhancement project is vital for understanding how the project aligns with the behaviors, attitudes, and acceptance levels of individuals involved, including both customers and staff. This assessment aims to ensure a smooth adoption of changes and a positive reception within the retail environment. It involves evaluating user acceptance among customers and staff, developing effective change management strategies to address resistance, assessing the impact on the overall customer experience, considering employee morale, and establishing feedback mechanisms to continuously refine the project based on real-time insights. The goal is to foster a positive and harmonious integration of the proposed changes, promoting a supportive environment for both customers and staff.

6.5. Time Feasibility

The time feasibility analysis for the proposed retail enhancement project is crucial for determining the practicality of implementing transformative changes within a defined timeframe. A well-structured implementation schedule, delineating key milestones and timelines for each project phase, is essential. This schedule considers potential dependencies and critical paths, ensuring an organized and efficient rollout that adheres to realistic timeframes.

Moreover, the analysis assesses the time required for the seamless integration of new technologies into existing systems. This includes factors such as thorough testing, comprehensive training, and potential adjustments to ensure a smooth transition without compromising operational efficiency or causing prolonged downtime

Additionally, the evaluation extends to understanding the adoption period for users, encompassing both customers and staff, to fully embrace and adapt to the proposed changes. Incorporating robust change management strategies facilitates a gradual and effective transition, acknowledging that behavioral shifts require time and support. To maintain agility and responsiveness, the analysis emphasizes the importance of iterative feedback cycles. These cycles enable continuous refinement of the project based on real-time insights, ensuring that any unforeseen challenges or necessary adjustments are addressed promptly. In essence, the time feasibility analysis aims to strike a balance between ambitious goals and pragmatic timelines, promoting a successful and timely implementation of the retail enhancement project.

6.6. Resource Feasibility

The resource feasibility analysis for the proposed retail enhancement project is crucial to assess the availability and adequacy of resources required for successful implementation. This evaluation encompasses various resources, including financial, human, and technological elements, ensuring that the project aligns with the organization's capabilities.

Financial feasibility is a key consideration, examining the budgetary allocation needed for technology implementation, staff training, and any potential unforeseen costs. This analysis aims to ensure that the project's financial requirements are realistic and align with the organization's budget constraints. Human resources play a vital role, and the analysis assesses the availability of skilled personnel required for implementing and managing the new technologies. It also considers the potential need for additional staff training to bridge any skill gaps.

Technological resources are scrutinized to determine if the existing infrastructure can support the proposed enhancements. This includes evaluating the compatibility of current systems with advanced technologies and assessing the need for any upgrades or integrations.

7. EXPERIMENTATION AND RESULT

7.1. Data Collection

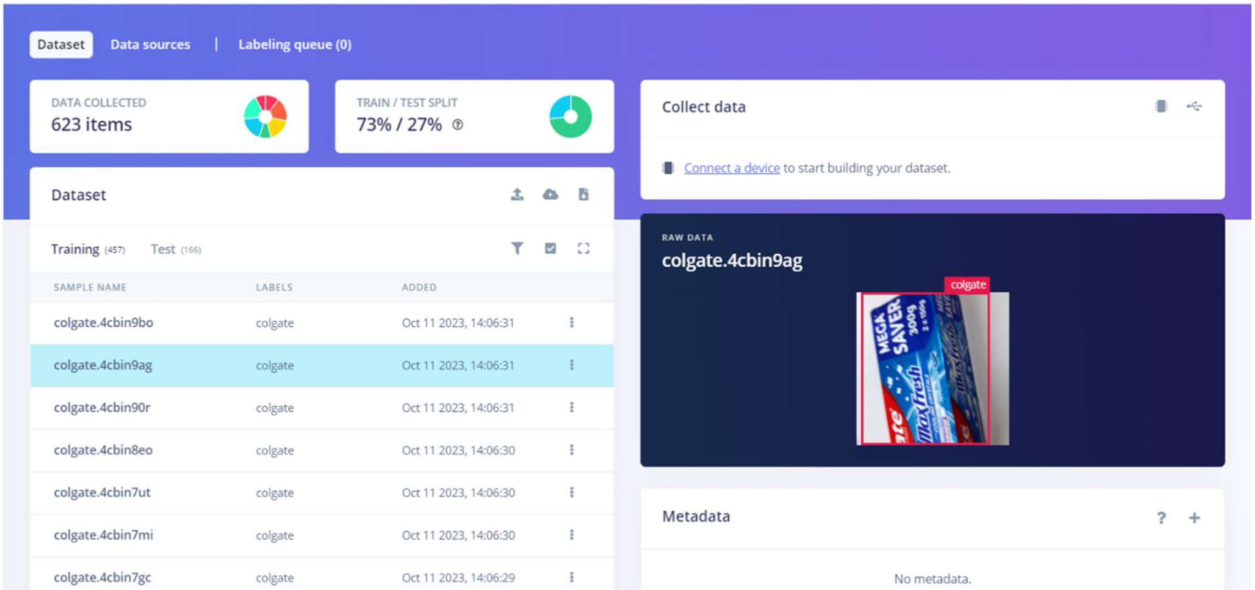


Fig 7.1.1. Data Collection

The Smart Store System utilizes image recognition technology to capture and catalog images of goods within supermarkets, facilitating a seamless self-checkout experience by automatically identifying and associating products with their corresponding prices. This innovative system enhances efficiency and accuracy in the checkout process.

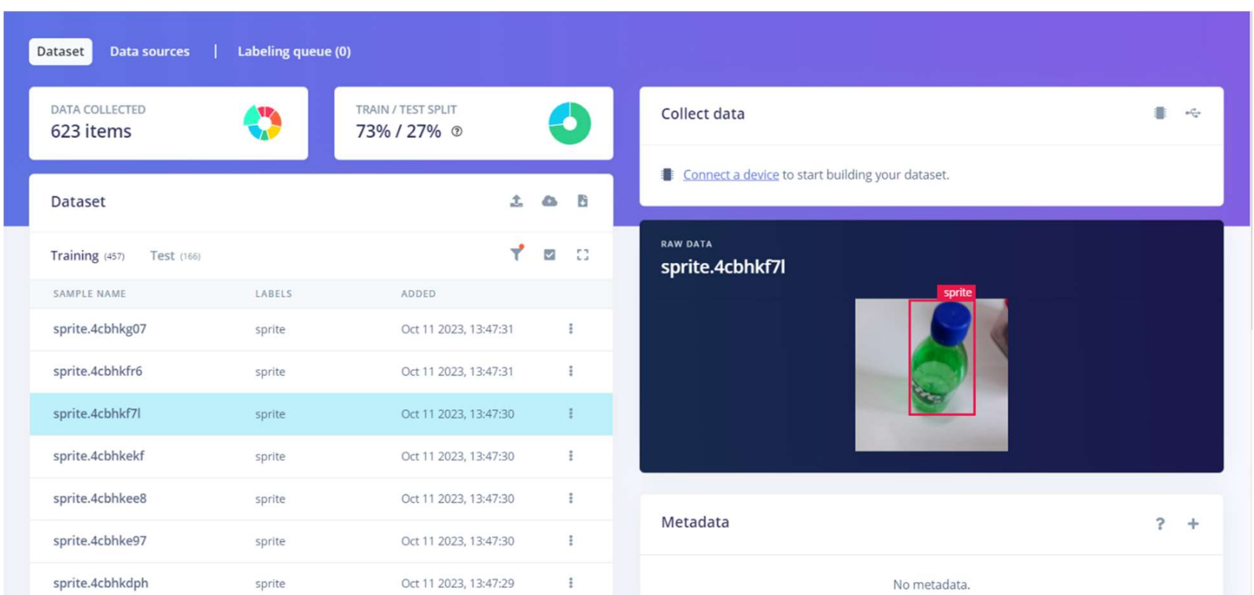


Fig 7.1.2. Data Collection

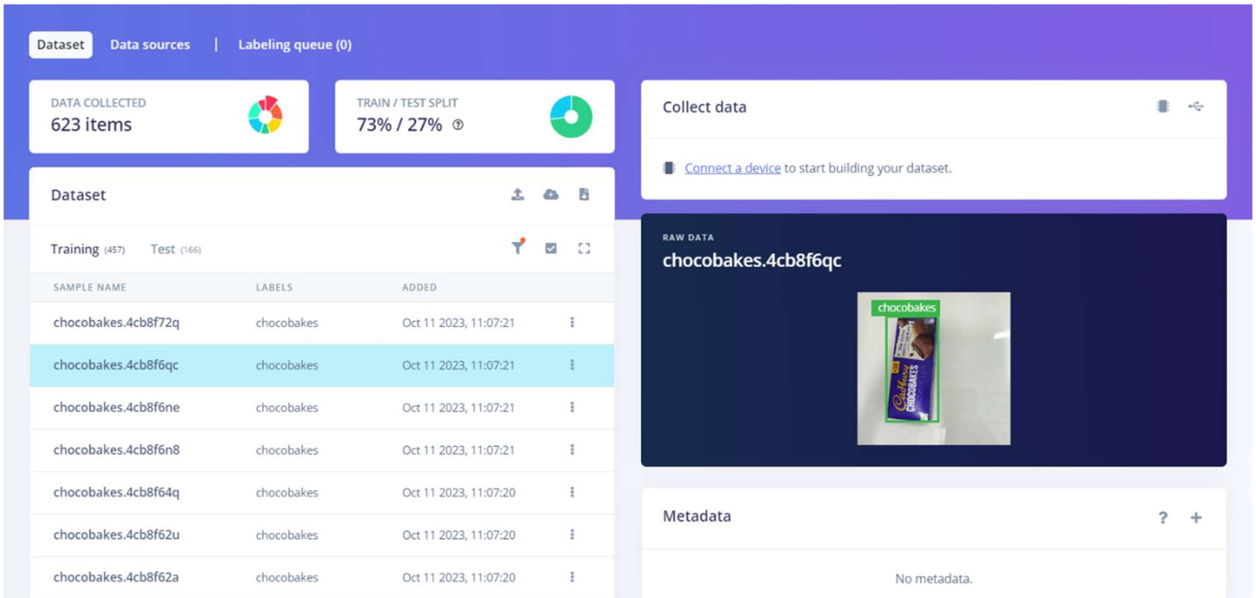


Fig 7.1.3. Data Collection

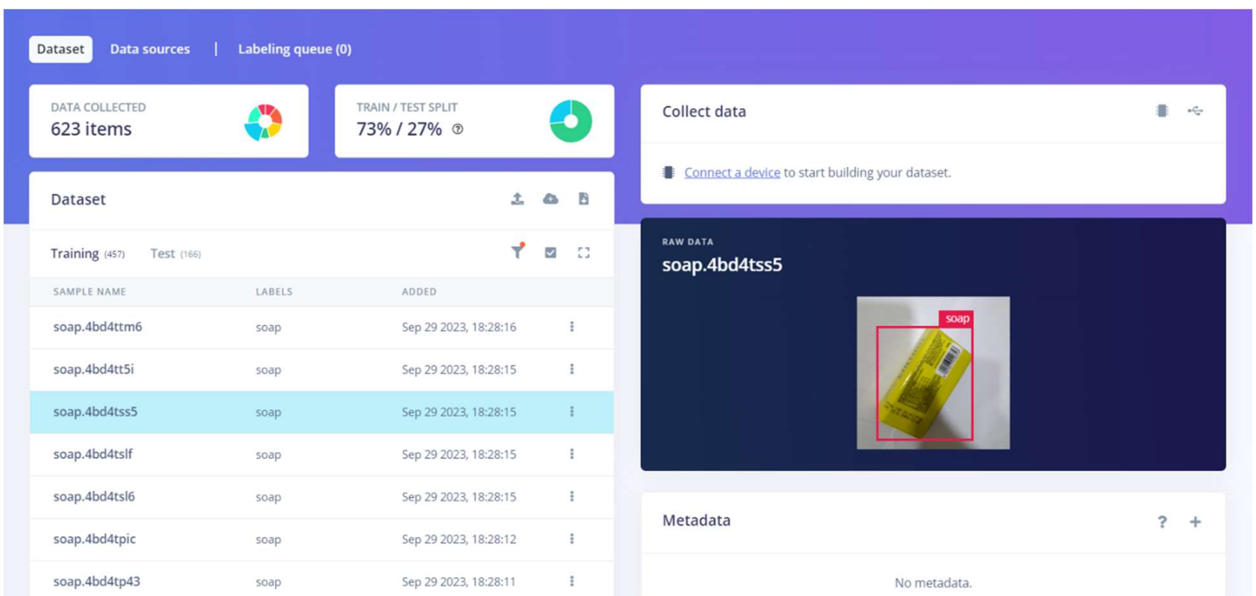


Fig 7.1.4. Data Collection

7.2. Feature Explorer

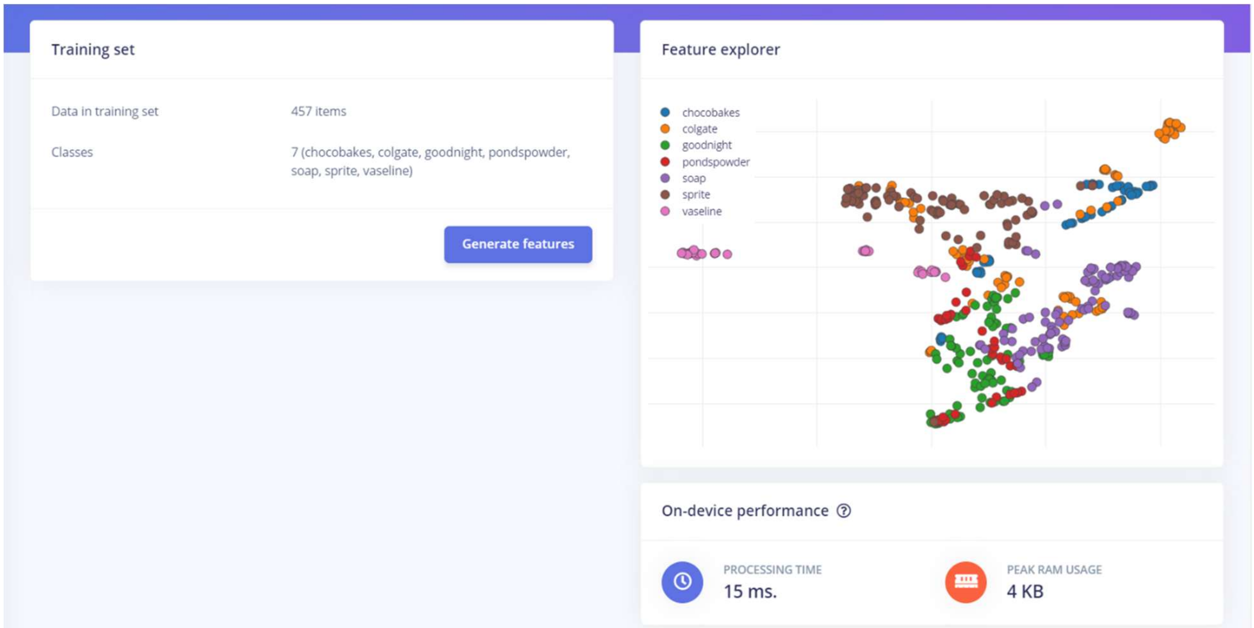


Fig. 7.2. Feature Explorer

Feature explorer is a tool or platform that allows users to interactively explore and analyze the features (columns or attributes) of a dataset. A feature explorer for data aims to make the process of exploring and understanding dataset features more interactive, intuitive, and informative. It should empower users to gain insights into the dataset's characteristics and relationships, supporting data-driven decision-making.

7.3. ML Model and Predictions

7.3.1 ML Model

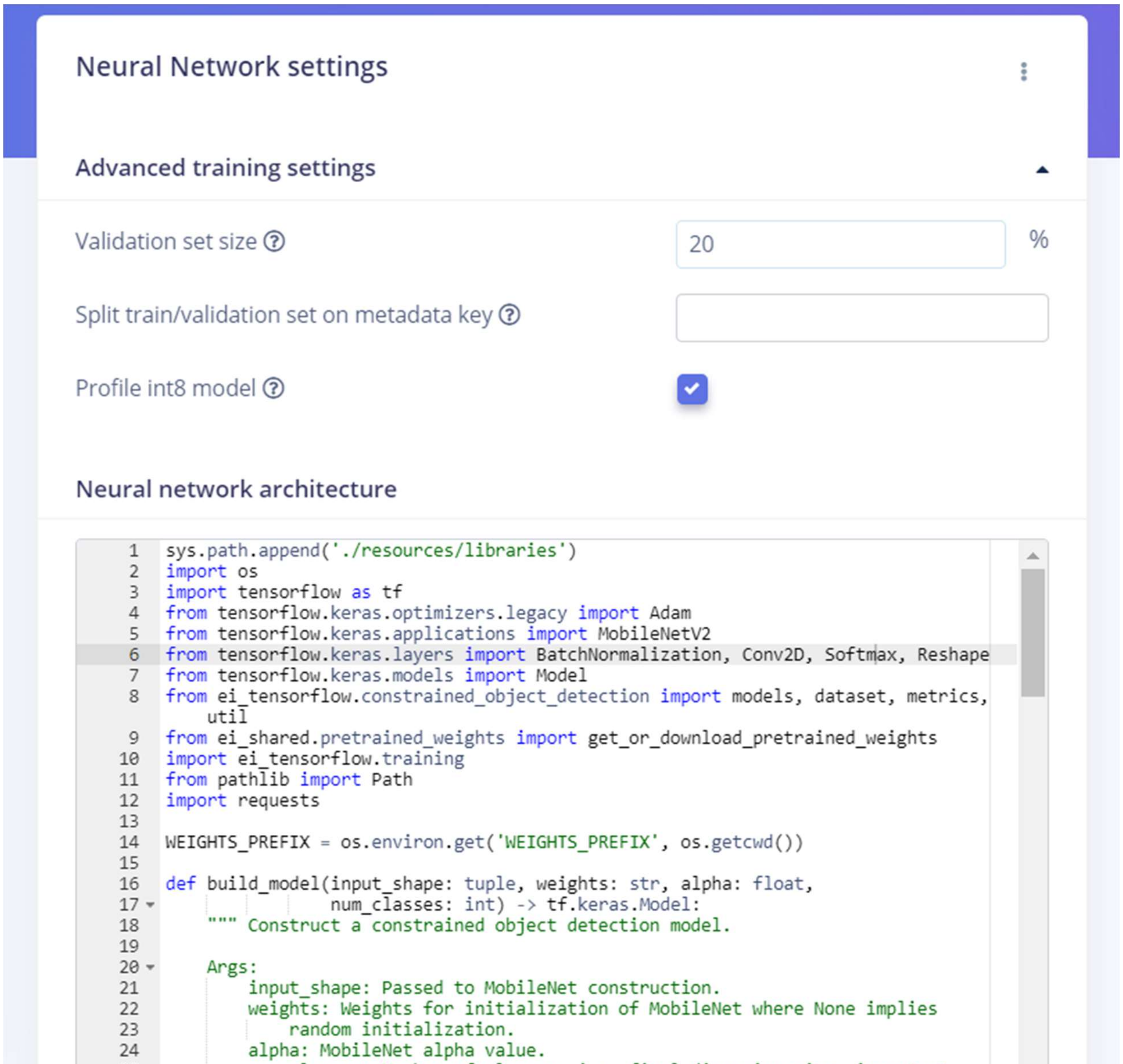


Fig 7.3.1 ML Model

ML model Program

```
sys.path.append('./resources/libraries')
import os
import tensorflow as tf
from tensorflow.keras.optimizers.legacy import Adam
from tensorflow.keras.applications import MobileNetV2
from tensorflow.keras.layers import BatchNormalization, Conv2D, Softmax,
Reshape
from tensorflow.keras.models import Model
from ei_tensorflow.constrained_object_detection import models, dataset, metrics,
util
from ei_shared.pretrained_weights import get_or_download_pretrained_weights
import ei_tensorflow.training
from pathlib import Path
import requests

WEIGHTS_PREFIX = os.environ.get('WEIGHTS_PREFIX', os.getcwd())

def build_model(input_shape: tuple, weights: str, alpha: float,
            num_classes: int) -> tf.keras.Model:
  """ Construct a constrained object detection model.

  Args:
    input_shape: Passed to MobileNet construction.
    weights: Weights for initialization of MobileNet where None implies
      random initialization.
    alpha: MobileNet alpha value.
    num_classes: Number of classes, i.e. final dimension size, in output.

  Returns:
    Uncompiled keras model.

  Model takes (B, H, W, C) input and
  returns (B, H//8, W//8, num_classes) logits.
  """

  #! First create full mobile_net_V2 from (HW, HW, C) input
  #! to (HW/8, HW/8, C) output
  mobile_net_v2 = MobileNetV2(input_shape=input_shape,
```

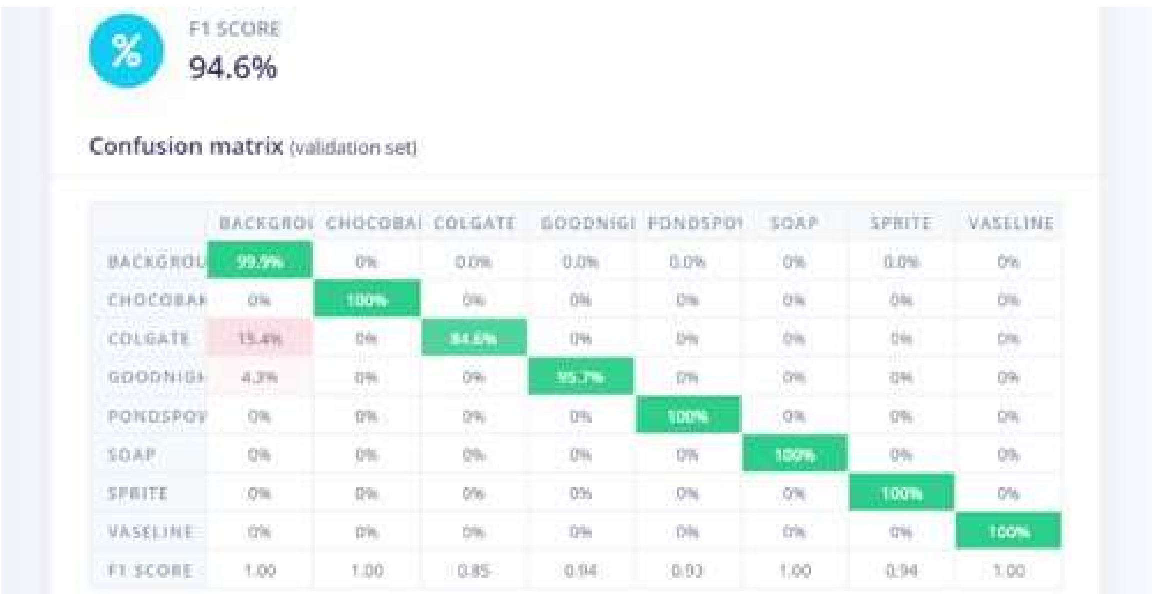
```
                       weights=weights,
                       alpha=alpha,
                       include_top=True)
    #! Default batch norm is configured for huge networks, let's speed it up
    for layer in mobile_net_v2.layers:
        if type(layer) == BatchNormalization:
            layer.momentum = 0.9
    #! Cut MobileNet where it hits 1/8th input resolution; i.e. (HW/8, HW/8, C)
    cut_point = mobile_net_v2.get_layer('block_6_expand_relu')
    #! Now attach a small additional head on the MobileNet
    model = Conv2D(filters=32, kernel_size=1, strides=1,
                activation='relu', name='head')(cut_point.output)
    logits = Conv2D(filters=num_classes, kernel_size=1, strides=1,
                    activation=None, name='logits')(model)
    return Model(inputs=mobile_net_v2.input, outputs=logits)

def train(num_classes: int, learning_rate: float, num_epochs: int,
          alpha: float, object_weight: float,
          train_dataset: tf.data.Dataset,
          validation_dataset: tf.data.Dataset,
          best_model_path: str,
          input_shape: tuple,
          batch_size: int,
          lr_finder: bool = False,
          ensure_determinism: bool = False) -> tf.keras.Model:

    nonlocal callbacks

    num_classes_with_background = num_classes + 1

    input_width_height = None
    width, height, input_num_channels = input_shape
    if width != height:
        raise Exception(f"Only square inputs are supported; not {input_shape}")
    input_width_height = width

    #! Use pretrained weights, if we have them for configured
    allowed_combinations = [{'num_channels': 1, 'alpha': 0.1},
                            {'num_channels': 1, 'alpha': 0.35},
                            {'num_channels': 3, 'alpha': 0.1},
                            {'num_channels': 3, 'alpha': 0.35}]
    weights = get_or_download_pretrained_weights(WEIGHTS_PREFIX,
input_num_channels, alpha, allowed_combinations)
```

```
    model = build_model(
        input_shape=input_shape,
        weights=weights,
        alpha=alpha,
        num_classes=num_classes_with_background
    )

    #! Derive output size from model
    model_output_shape = model.layers[-1].output.shape
    _batch, width, height, num_classes = model_output_shape
    if width != height:
        raise Exception(f"Only square outputs are supported; not
{model_output_shape}")
    output_width_height = width

    #! Build weighted cross entropy loss specific to this model size
    weighted_xent = models.construct_weighted_xent_fn(model.output.shape,
object_weight)

    prefetch_policy = 1 if ensure_determinism else
tf.data.experimental.AUTOTUNE

    #! Transform bounding box labels into segmentation maps
    def as_segmentation(ds, shuffle):
        ds = ds.map(dataset.bbox_to_segmentation(output_width_height,
num_classes_with_background))
        if not ensure_determinism and shuffle:
            ds = ds.shuffle(buffer_size=batch_size*4)
        ds = ds.batch(batch_size, drop_remainder=False).prefetch(prefetch_policy)
        return ds

    train_segmentation_dataset = as_segmentation(train_dataset, True)
    validation_segmentation_dataset = as_segmentation(validation_dataset, False)

    validation_dataset_for_callback = (validation_dataset
        .batch(batch_size, drop_remainder=False)
        .prefetch(prefetch_policy))

    #! Initialise bias of final classifier based on training data prior.
    util.set_classifier_biases_from_dataset(
        model, train_segmentation_dataset)
```

```
    if lr_finder:
        learning_rate = ei_tensorflow.lr_finder.find_lr(model,
train_segmentation_dataset, weighted_xent)
    model.compile(loss=weighted_xent,
                  optimizer=Adam(learning_rate=learning_rate))

    #! Create callback that will do centroid scoring on end of epoch against
    #! validation data. Include a callback to show % progress in slow cases.
    callbacks = callbacks if callbacks else []
    callbacks.append(metrics.CentroidScoring(validation_dataset_for_callback,
                                             output_width_height, num_classes_with_background))
    callbacks.append(metrics.PrintPercentageTrained(num_epochs))

    #! Include a callback for model checkpointing based on the best validation f1.
    callbacks.append(
        tf.keras.callbacks.ModelCheckpoint(best_model_path,
            monitor='val_f1', save_best_only=True, mode='max',
            save_weights_only=True, verbose=0))

    model.fit(train_segmentation_dataset,
              validation_data=validation_segmentation_dataset,
              epochs=num_epochs, callbacks=callbacks, verbose=0)

    #! Restore best weights.
    model.load_weights(best_model_path)

    #! Add explicit softmax layer before export.
    softmax_layer = Softmax()(model.layers[-1].output)
    model = Model(model.input, softmax_layer)

    return model


EPOCHS = args.epochs or 60
LEARNING_RATE = args.learning_rate or 0.001
BATCH_SIZE = args.batch_size or 32

model = train(num_classes=classes,
              learning_rate=LEARNING_RATE,
              num_epochs=EPOCHS,
              alpha=0.1,
              object_weight=100,
              train_dataset=train_dataset,
```

```
        validation_dataset=validation_dataset,
        best_model_path=BEST_MODEL_PATH,
        input_shape=MODEL_INPUT_SHAPE,
        batch_size=BATCH_SIZE,
        lr_finder=False,
        ensure_determinism=ensure_determinism)


override_mode = 'segmentation'
disable_per_channel_quantization = False
```

7.3.2 Model Predictions



	BACKGROU	CHOCOBAI	COLGATE	GOODNIGI	PONDSPOI	SOAP	SPRITE	VASELINE
BACKGROU	99.9%	0%	0.0%	0.0%	0.0%	0%	0.0%	0%
CHOCOBAI	0%	100%	0%	0%	0%	0%	0%	0%
COLGATE	15.4%	0%	84.6%	0%	0%	0%	0%	0%
GOODNIGI	4.3%	0%	0%	95.7%	0%	0%	0%	0%
PONDSPOV	0%	0%	0%	0%	100%	0%	0%	0%
SOAP	0%	0%	0%	0%	0%	100%	0%	0%
SPRITE	0%	0%	0%	0%	0%	0%	100%	0%
VASELINE	0%	0%	0%	0%	0%	0%	0%	100%
F1 SCORE	1.00	1.00	0.85	0.94	0.93	1.00	0.94	1.00

Fig 7.3.2. ML Model Predictions

Evaluating the F1 score, along with precision and recall, provides a comprehensive understanding of the model's performance, especially in scenarios where class imbalances exist. Adjusting the model and parameters based on these metrics helps in achieving a balance between correctly identifying positive instances and minimizing false positives.

7.4. Model Testing

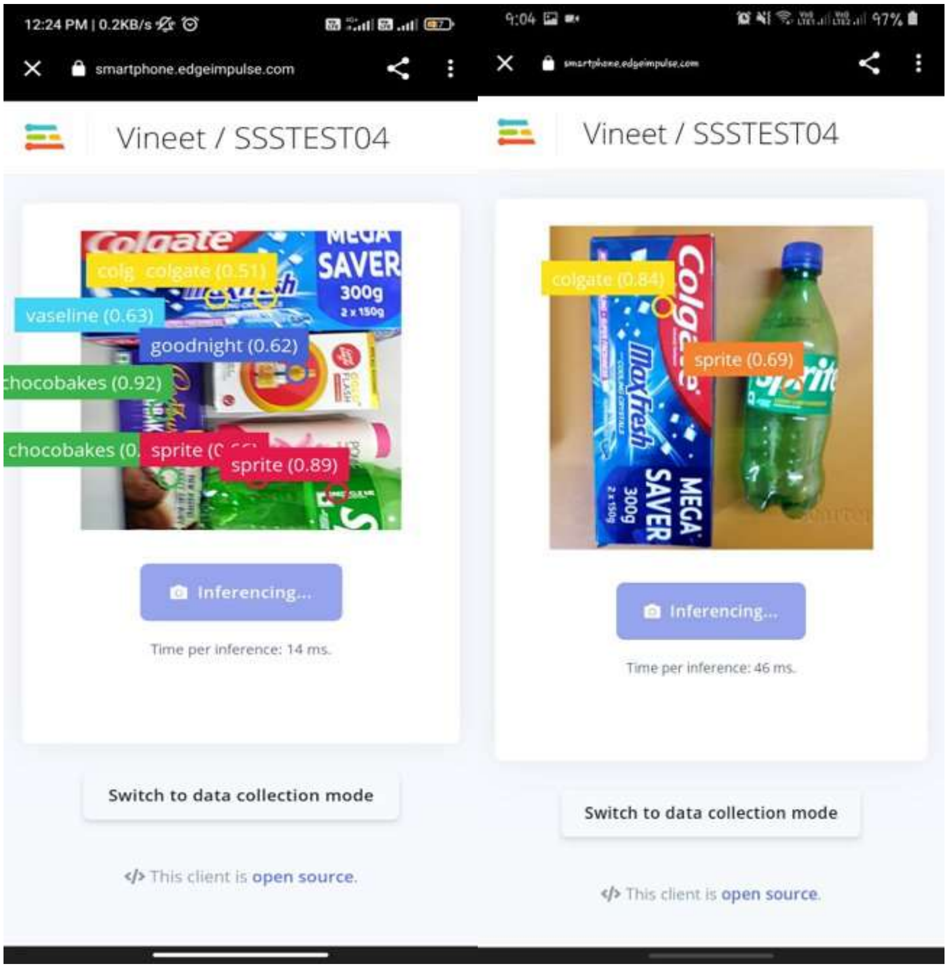


Fig. 7.4.1 Model Testing

Testing a model and evaluating its performance on a separate dataset is crucial for assessing its generalization capabilities. It helps identify potential issues, such as overfitting or underfitting, and guides improvements to enhance model effectiveness in real-world scenarios.

7.5. Object Detection

Fig. 7.5.1. Object Detection

Fig. 7.5.2. Object Detection

Object detection in a self-checkout smart store system enhances the user experience by automating the identification of items in the shopping cart. The choice of the object detection model should align with the requirements of real-time processing, accuracy, and the specific characteristics of items in your store.

8. CONCLUSION

Self-checkout smart stores revolutionize the shopping experience by providing enhanced convenience through quick payments and eliminating long queues, saving customers valuable time, and reducing frustration. The user-friendly interface contributes to improved customer satisfaction by minimizing checkout bottlenecks and reducing human errors. Additionally, the integration of advanced security measures, including surveillance cameras, leads to a reduction in theft and fraud, enhancing store profitability. In response to the growing demand for contactless experiences, these smart stores offer a safer shopping option by minimizing physical interactions during the checkout process. Overall, the adoption of self-checkout technology brings about a more seamless, efficient, and secure retail environment, meeting the evolving preferences of modern consumers.

1) Enhanced Convenience: Self-checkout smart stores provide shoppers with a more seamless and efficient shopping experience. Customers can quickly make payments, and exit the store without waiting in long queues, saving valuable time, and reducing frustration.

2) Improved Customer Satisfaction: With fewer checkout bottlenecks and a user-friendly interface, customers experience higher satisfaction levels when shopping at smart stores. The reduction in human error during the checkout process also contributes to a more positive shopping experience.

3) Reduced Theft and Fraud: The integration of advanced security measures, such as surveillance cameras, helps minimize theft and fraud instances, improving store profitability and loss prevention efforts.

4) Contactless Shopping: In growing demand for contactless experiences, self-checkout smart stores offer a safer shopping option, minimizing physical interactions.

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