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Smart Shopping Cart and Demand Prediction System

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ABSTRACT

This article presents a smart shopping cart and demand prediction system implemented using Raspberry Pi and Ardiuno microcontrollers. The absence of autonomous shopping carts or guided assistance systems prolongs the shopping journey, as customers must manually push carts and navigate through store aisles, consuming valuable time and energy. Conventional checkout procedures often lead to delays, especially during peak hours, as customers contend with queues for manual billing and payment transactions. This not only frustrates customers but also affects overall store efficiency. Without access to real-time consumer behaviour insights, customers miss out on personalized recommendations and tailored offers that could enhance their shopping journey. The autonomous shopping cart solves the above mentioned problems and aids the demand prediction system by providing the required data.

Keywords **—** supermarket robot, automated billing, demand prediction, microcontroller

I. INTRODUCTION

Our innovative intelligent supermarket service robot represents a transformative leap forward in retail technology, poised to revolutionize the shopping experience and optimize supermarket operations. At its core, our system is engineered to deliver personalized assistance and seamless functionality through an array of advanced features, including human following, product recognition, customer interaction, and automated billing.

Central to the system's architecture is the utilization of cutting-edge hardware components, strategically integrated for maximum efficiency and performance. Complementing the Raspberry Pi's capabilities, an Arduino Uno serves as the backbone of our human tracking and following functionalities. By employing precise distance maintenance techniques, the robot navigates through the supermarket environment autonomously, tailoring its movements to accommodate customers' pace and preferences.

The significance of our system extends beyond individual convenience to encompass strategic insights that drive operational excellence for store owners and managers. Through continuous data collection and analysis, our robot compiles valuable information on customer preferences, purchasing habits, and traffic patterns within the supermarket. This wealth of data empowers decision-makers to optimize inventory management strategies, refine product placement, and tailor marketing initiatives to align with evolving consumer behaviours.

Qingqing Yuan et al., developed an Intelligent Shopping Cart utilizing ultrasonic sensor and monocular camera for uman tracking [1]. A supermarket service robot based on Raspberry Pi is designed by Xue Han et al. [2]. A product detection and billing system implemented using Raspberry Pi and open CV is reported in [3]. Machine learning based demand prediction is demonstrated by Muhammad Adnan Khan et al. [4]. These literatures inspired us to develop our smart cart and inventory prediction system.

II. MOTIVATION

Supermarkets and retail stores encounter significant operational challenges characterized by persistent issues such as prolonged queues and suboptimal customer management, particularly within the billing sections. The resultant long waiting times not only inconvenience patrons but also impose additional burdens on store personnel, exacerbating overall operational inefficiencies. Concurrently, the absence of robust inventory management techniques necessitates continual manual oversight of product sales and stock levels, leading to frequent out-of-stock scenarios and further amplifying the workload on store employees.

The main advantages of the developed system are given below.

A. Enhanced Customer Experience with Automated Checkout

Automated checkout systems offer a transformative solution to reduce long queues and enhance customer service within supermarkets and retail stores. By expediting the checkout process through automated transactions, customers benefit from reduced waiting times and increased convenience, leading to improved overall satisfaction.

B. Optimized Inventory Management with Automation

The constant manual monitoring of inventory levels by store staff often results in out-of-stock situations and heightened workload. Introducing automated inventory management systems enables real-time monitoring and predictive analytics, mitigating stock shortages and alleviating the burden on store personnel.

C. Streamlined Operations through Automation

Automated solutions play a pivotal role in streamlining checkout processes and optimizing inventory management by leveraging demand prediction algorithms. By accurately forecasting product demands based on historical data and market trends, supermarkets can efficiently allocate resources and minimize operational inefficiencies.

III. SMART CART SYSTEM

The smart cart system consists of two main modules, (i) Robot module for autonomous navigation in congested store and following the customer, and (ii) product recognition system using machine learning algorithm for product identification and automated billing.

A. Implementation Details

Fig. 1 shows the functional units and components of the customer following module. This module is built around the Ardiuno microcontroller with ultrasonic sensor for human sensing, ranging and obstacle detection.

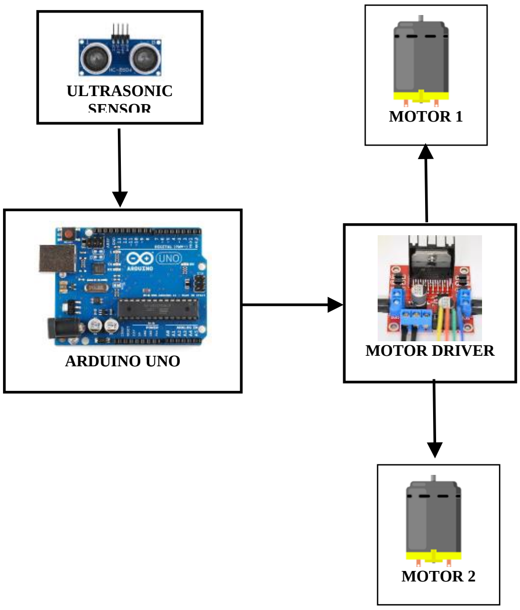

Fig. 1 Block diagram of the smart cart - Robot module

Wheeled motors are provided for navigation. Ardiuno IDE is used to write and load the code in the Ardiuno board. Fig. 2 shows the block diagram of the product identification module, which is built on Raspberry Pi microcontroller. PI CAM sensor is used for image capturing and the trained machine learning model identifies and displays the product. Using the dedicated camera module, the system captures high-resolution images and video feeds essential for precise object detection.

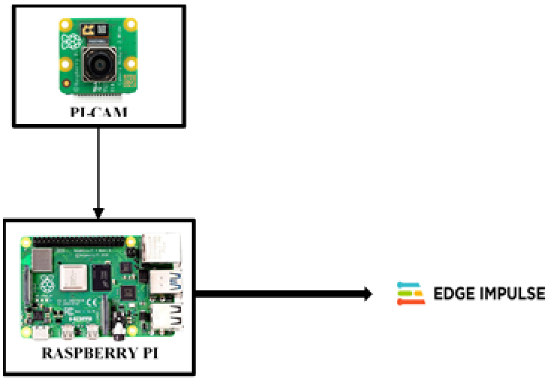

Fig. 2 Block diagram of the smart cart – Product detection module

This module also houses an automatic bill preparation program. Edge Impulse is used to train an ML model, integrate it with the Raspberry Pi and acquire live video and images through camera interfacing.

Fig. 3 Example image samples

Dataset of sample images of six sample products are created using PI-CAM captures. The dataset consisted of 100 sample images of each of the six products with different orientations. Few example images from the data set are given in Fig. 3. The training and test data consisted of 80% and 20% of the randomly selected images of each product from the dataset.

B. Performance

Accuracy of prediction is the most important performance metric for a classifier, which gives the percentage of correct classifications made by the model. The accuracy performance of the product detection system depends on various factors like the quality and number of training samples, the input imagery and model parameters.

```
Accuracy for Pepsi: 93.61%
Accuracy for 50&50: 74.57%
Accuracy for Marie Gold: 88.36%
Accuracy for Coke: 85.93%
Accuracy for Bingo: 98.05%
Accuracy for Lays: 89.30%
```

Fig. 4 Screenshot showing test accuracy for different products

The screenshot displaying the accuracy metric is shown in Fig. 4. Though the accuracy achieved while testing the recorded image samples of test set exceeds 96% for all the six products, the test accuracy for live samples is lesser for most cases.

```
====================== INVOICE ======================
Product Number | Product Name | Price | Quantity | Amount
=====================================================
2              | Lays         | 10    | 2        | 20
3              | Kurkure      | 10    | 1        | 10
1              | Coke         | 40    | 1        | 40

Amount Payable: 70.00
=====================================================
```

Fig. 5 Screenshot of bill generated

Fig. 5 shows the output of automated bill generation program for an example run of three identified products.

IV. DEMAND PREDICTION SYSTEM

The lack of continuous monitoring of stock levels contributes to frequent out-of-stock scenarios. Customers are left disappointed when desired items are unavailable, leading to potential loss of sales and diminished customer satisfaction. The smart cart system gathers valuable data on customer preferences, product movement, and inventory levels. This data can serve as a foundation for demand forecasting and informed decision-making, empowering supermarkets to optimize stock levels and enhance operational performance.

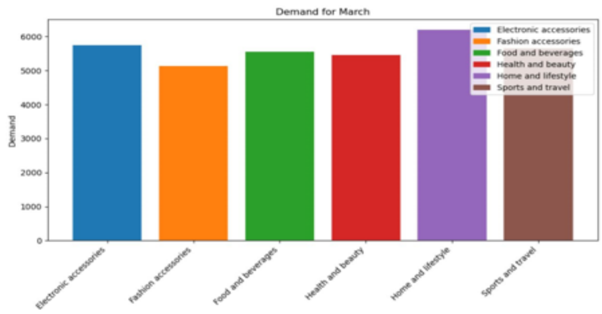

Fig. 6 Plot of actual demand

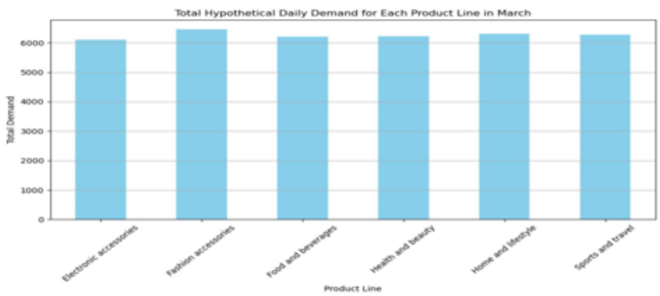

Fig.7 Plot of predicted demand

```
Accuracy for Electronic accessories: 93.61%
Accuracy for Fashion accessories: 74.57%
Accuracy for Food and beverages: 88.36%
Accuracy for Health and beauty: 85.93%
Accuracy for Home and lifestyle: 98.05%
Accuracy for Sports and travel: 89.30%
```

Fig.8 Prediction accuracy analysis report

A linear regression model is created and trained to perform demand prediction. The super market sales data set available online [5] is used for testing the model which is based on real world data collected over three months. The prediction is done for the month of march based on the previous two months. The prediction accuracy result is shown in Fig.8 for the different product categories.

V. CONCLUSIONS

By combining personalized assistance, efficient product management, and data-driven insights, our system redefines the parameters of modern retail, empowering supermarkets to operate with agility, foresight, and unwavering commitment to customer satisfaction. Through this holistic approach, we pave the way for a new era of retail excellence, where innovation and customer-centricity converge to shape the future of shopping.

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