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Navi-cart: Revolutionizing the Retail Shopping Experience with 5G-Powered Indoor Navigation and Autonomous Billing

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Abstract: The Navi-cart is an innovative shopping cart designed to revolutionize the retail shopping experience by integrating cutting-edge technologies. Central to its design is 5G-powered indoor navigation, which facilitates real-time data processing and seamless connectivity between hardware and software components. Navi-cart employs high-resolution cameras and advanced sensors to automatically detect items, manage billing, and avoid obstacles, making shopping faster and error-free. The cart is powered by an intelligent software module, I-cart, which includes a virtual assistant to provide real-time product recommendations, locate items, and answer customer queries. By addressing common challenges like long checkout queues and difficulty in locating products, Navi-cart redefines modern retail by ensuring convenience, efficiency, and satisfaction for all stakeholders.

Index Terms - Smart shopping cart, 5G, indoor navigation, automated billing, object detection.

I. INTRODUCTION

The retail industry is undergoing a digital transformation, driven by advancements in smart technologies. Traditional shopping often poses challenges such as long checkout queues, difficulty finding desired products, and a lack of personalized service. Navi-cart aims to overcome these challenges by integrating state-of-the-art hardware and intelligent software to provide a seamless and efficient shopping experience.

Navi-cart combines advanced hardware components, including high-resolution cameras, ultrasonic sensors, and motorized wheels, all orchestrated by a Raspberry Pi processor. These elements enable automated billing, real-time obstacle detection, and human-following capabilities. The inclusion of 5G technology ensures ultra-fast data transmission, enabling the system to process and respond to user interactions instantly.

With its robust integration of hardware and software, Navi-cart not only enhances customer convenience but also optimizes store operations. Retailers can reduce dependency on staff for manual tasks, streamline checkout processes, and gather valuable insights into consumer behavior. This paper delves into the features and methodology behind Navi-cart and its potential to revolutionize the retail landscape.

II. Related Works

Recent advancements in smart shopping systems and indoor navigation technologies have significantly reshaped the retail landscape. The Navi-cart builds upon various innovative technologies, integrating autonomous navigation, real-time billing, and 5G communication to enhance the shopping experience.

Object detection and recognition in dynamic retail environments have been extensively studied. Zhang et al. explored motion segmentation techniques for moving cameras, essential for detecting objects in dynamic environments [1]. Kalayci et al. benchmarked high-performance object detection techniques [3], highlighting computational efficiency in smart carts.

To address the growing need for real-time data management in smart retail environments, Raetsi-Varzaneh et al. proposed resource scheduling methods in edge computing scenarios [2]. Their research aligns with Navi-cart's real-time data processing needs.

For human and object tracking, Ninh et al. integrated collaborative multi-object tracking techniques [4], which are instrumental in crowded retail environments. Islam et al. developed stereo vision-based tracking for precise object localization [7], further enhancing autonomous cart capabilities.

In billing automation, Aslam et al. used RFID-based systems for streamlined billing processes [5]. Similarly, Yao et al. introduced radar-based sensor fusion for self-following smart carts [6], facilitating advanced obstacle detection and navigation.

Recommender systems for personalized shopping experiences have also evolved. Dhelim et al. presented personality-aware product recommendation methods using user interest mining [7], aligning with Navi-cart's virtual assistant feature.

Figure 1: NaviCart Model

III. Hardware Components

A. Obstacle Detection

Ultrasonic sensors are positioned around the cart to detect nearby obstacles and calculate distances. The sensors provide real-time feedback to the processor, which adjusts the cart's movement to avoid collisions.

B. Motorized Wheels

Controlled by motor drivers, these wheels enable the cart's autonomous movement. The processor sends signals to adjust speed and direction based on navigation requirements.

C. 5G Connectivity Module

Ensures high-speed data transfer between the cart and the store's central server. This connectivity supports real-time updates on inventory, pricing, and shopper preferences..

D. Battery System

A rechargeable battery powers all hardware components. Efficient power management algorithms optimize energy consumption, extending operational time and ensuring uninterrupted service.

E. Built-In Display Screen

This interactive screen provides a user interface for shoppers, showing item details, running totals, and personalized recommendations. It also serves as an interface for the virtual assistant.

IV. Mathematical Model for Object Detection and Navigation

The navigation system of Navi-cart follows an optimized movement strategy based on the detected object's position:

$$Speed = \min(5, \max(3, 6 \cdot Relativepos))$$

For obstacle avoidance, Navi-cart follows a path adjustment model: where D is the set of movement directions and P(d) represents the probability of a safe path.

IV. AUTOMATED BILLING SYSTEM

Navi-cart eliminates traditional checkout queues through its automated billing system, powered by object detection algorithms. When items are placed in the cart, the system identifies them and updates the virtual shopping list on the display screen.

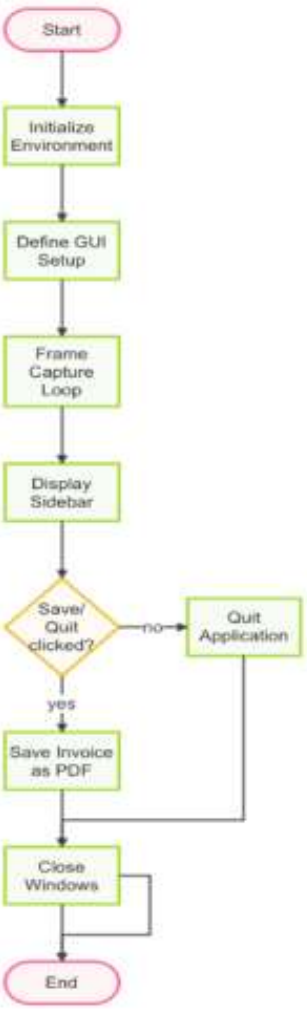

Figure 2: Automatic Billing System flow chart

A. Pseudo Code for Automated Billing.

1: Load YOLO model
2: Initialize camera
3: while program is running do
4: Capture frame from camera
5: Run YOLO model to detect objects
6: for each detected object do
7: if object in inventory database then
8: Add item to virtual shopping list
9: Update total price
10: end if
11: end for
12: Display updated shopping list and total price
13: if checkout initiated then
14: Generate invoice and process payment
15: end if
16: end while
17: Terminate program

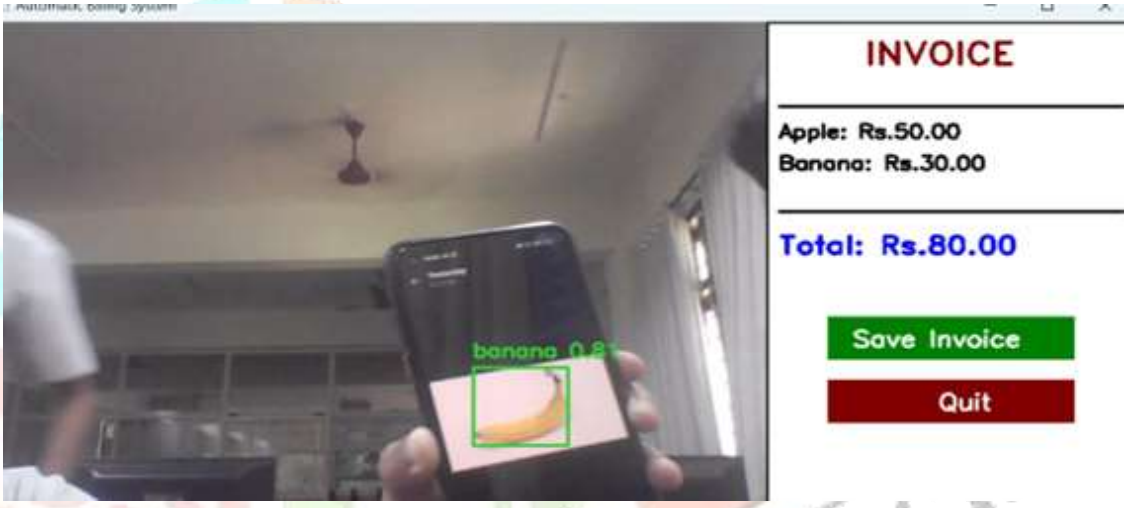

Figure 3: Automatic billing system

V. FUTURE SCOPE

Future enhancements include:

1. **Enhanced Item Recognition:** Improved AI-based object detection.
2. **Augmented Reality (AR):** Real-time item tracking and interaction.
3. **Voice-Activated Assistance:** Natural language processing for voice commands.
4. **Accessibility Features:** Voice-guided navigation for differently-abled users.
5. **IoT and Mobile Integration:** Remote cart control via mobile apps.
6. **Dynamic Pathfinding:** AI-driven route optimization based on store conditions.

VI. CONCLUSION

Navi-cart integrates advanced hardware and intelligent software to redefine the in-store shopping experience. It automates routine tasks, optimizes store operations, and enhances customer convenience through real-time navigation, billing, and interaction. With continued advancements in AI and IoT, Navi-cart has the potential to revolutionize retail shopping globally.

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