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IOT INTEGRATED AI SHOPPING CART FOR INDIVIDUALS WITH VISUALLY IMPAIRED

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ABSTRACT

Shopping independently remains a challenge for visually impaired individuals due to the inability to identify products and navigate within a store.

This paper presents a Smart Shopping Trolley integrating Internet of Things (IoT) and Artificial Intelligence (AI) to enhance accessibility for visually impaired users. The system employs a Raspberry Pi as the central processing unit, interfacing with an RFID module for product identification, a voice module for audio feedback, and a camera for real-time object detection. A buzzer aids in navigation, while a Wi-Fi module ensures cloud connectivity for smart assistance. This smart trolley provides a hands-free, interactive shopping experience, allowing users to receive real-time voice-based information about the products they select. The proposed system enhances independence, convenience, and efficiency for visually impaired individuals in retail environments.

Keywords- Smart Shopping Trolley, IoT, AI, Visually Impaired, Raspberry Pi, RFID, Voice Assistance, Object Detection, Accessibility, Assistive Technology.

I. INTRODUCTION

Shopping independently in supermarkets presents numerous challenges for visually impaired individuals. The inability to identify products, read price tags, or navigate store aisles without assistance often leads to dependency on others, reducing their autonomy. While existing solutions such as barcode scanners and human assistance provide some relief, they lack efficiency and real-time interaction, limiting the overall shopping experience for visually impaired users.

With the rapid advancements in Internet of Things (IoT) and Artificial Intelligence (AI), assistive technologies have become more intelligent and accessible.

This paper proposes a Smart Shopping Trolley that enhances independent shopping for visually impaired individuals by integrating Raspberry Pi with an RFID-based product identification system, a voice module for real-time audio feedback, and a camera for AI-powered object detection. Additionally, a buzzer system assists in navigation by alerting users to potential obstacles, while a Wi-Fi module ensures cloud connectivity for real-time updates and smart recommendations.

By leveraging IoT and AI, the proposed smart trolley provides a hands-free, voice-guided shopping experience, allowing users to navigate stores and obtain product details effortlessly.

This innovation aims to bridge the accessibility gap in shopping environments, offering visually impaired individuals a more inclusive and independent retail experience.

II. RELATED WORKS

Various assistive technologies have been developed to enhance the shopping experience for visually impaired individuals, focusing on product identification, navigation assistance, and voice-based interaction. This section reviews notable approaches and their limitations.

Various assistive technologies have been developed to enhance the shopping experience for visually impaired individuals. These approaches focus on **product identification, navigation assistance, and voice-based interaction**. This section reviews notable research contributions in these areas.

2.1 RFID and Barcode-Based Systems- Several studies have proposed **RFID-based** and **barcode-scanning** solutions for product identification. **Prabhakar et al.** introduced an RFID-based smart shopping system that allows customers to scan products using RFID readers integrated into shopping carts, facilitating e-billing and reducing checkout time (Prabhakar et al., 2021). Similarly, **Chindamani et al.** developed a smart trolley equipped with an RFID reader and GSM module to automate billing and enhance the shopping experience (Chindamani et al., 2020). Although these systems improve efficiency, they require precise manual scanning, which can be challenging for visually impaired users.

2.2 AI-Powered Object Recognition Systems

Advancements in **computer vision and AI** have enabled object recognition-based assistive technologies. **Nawar et al.** proposed "Netra," an RFID-based Android application designed to help visually impaired individuals identify and locate personal items using RFID tags and a mobile device (Nawandar et al., 2021). While effective for personal item identification, such systems may not scale well in dynamic retail environments with a large number of products. Additionally, **Singh et al.** explored convolutional neural networks (CNNs) for product recognition, integrating AI-powered image processing into smart shopping trolleys (Singh et al., 2019). AI-based solutions, however, require substantial computational power and stable internet connectivity, which may not always be feasible.

2.3 Voice-Guided Shopping Assistance- Voice-guided assistance has been incorporated into shopping aids through **text-to-speech (TTS) engines** and **voice command modules**. **Gayathri et al.** presented a guiding system for smart shopping that provides audio commands to assist visually impaired individuals in navigating supermarkets and identifying products (Gayathri et al., 2020). Another work by **Kumar et al.** introduced a voice-controlled shopping assistant using Bluetooth and Wi-Fi connectivity, which enables users to interact with the system via voice commands (Kumar et al., 2021). These solutions improve accessibility but often rely on preloaded databases, limiting adaptability to dynamic store environments.

2.4 IoT-Based Smart Shopping Solutions

IoT has enabled **real-time assistance and navigation** in smart shopping systems. **Masadeh et al.** developed an IoT-based smart trolley that utilizes RFID sensors and infrared sensors to assist visually impaired users in navigating stores (Masadeh et al., 2022). Similarly, **Reddy et al.** proposed a cloud-connected smart cart system that integrates AI-based recommendation models, allowing visually impaired users to receive personalized product suggestions (Reddy et al., 2021). While promising, these systems require store-wide IoT infrastructure, making implementation challenging in smaller retail environments.

2.5 Wearable Assistive Technologies- In addition to smart shopping carts, researchers have explored **wearable technologies** for assisting visually impaired shoppers. **Sharma et al.** designed smart glasses with embedded AI and text-to-speech capabilities, allowing users to scan product labels and receive auditory feedback (Sharma et al., 2020). Another approach by **Ghosh et al.** involved the development of a smart glove with haptic feedback to help users navigate store aisles safely (Ghosh et al., 2019). Although wearable devices provide a hands-free experience, they may not be user-friendly for all individuals, particularly those unfamiliar with advanced technology.

2.6 Limitations of Existing Systems- Despite various technological advancements, existing solutions exhibit certain limitations:

RFID and barcode-based systems require precise alignment and manual scanning, posing challenges for visually impaired users.

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AI-powered recognition systems demand significant processing power and may struggle in cluttered retail environments.

Voice-guided systems often depend on preloaded databases, limiting flexibility in dynamic store settings.

IoT-based systems may require specific infrastructure, hindering scalability and widespread implementation.

III. PROPOED SYSTEM

The proposed system aims to assist visually impaired individuals in shopping independently by integrating IoT, AI-based object recognition, and RFID technology into a smart shopping trolley. This system provides voice-based assistance, automatic product identification, and real-time navigation guidance, ensuring a seamless and user-friendly shopping experience. The trolley is built around a Raspberry Pi, which acts as the central processing unit, managing all system operations. Each product in the store is tagged with an RFID label, which the trolley's RFID reader detects to retrieve product details. In cases where an RFID tag is missing, a Raspberry Pi camera is used for AI-based object detection to classify and identify the product. The extracted product information, including the name, price, and description, is then relayed to the user through a voice module, ensuring easy accessibility. For navigation assistance, the trolley is equipped with sensors and a buzzer to detect obstacles and alert the user about potential hazards. The system may also integrate predefined store layouts to guide users toward specific product sections. Additionally, a Wi-Fi module ensures cloud connectivity, allowing real-time updates and seamless integration with store databases. A monitor and an HDMI to VGA converter are included for visual display purposes, which can assist store staff in monitoring the system when required. The shopping process begins when the user places an item in the trolley. The RFID reader scans the product, retrieves the necessary information, and announces it through the voice module. If the product lacks an RFID tag, the camera module captures the item's image, and AI-based image recognition determines the product category. The trolley continuously updates the virtual cart, maintaining a real-time total of the selected items. At the checkout stage, the system generates a final bill, which can be sent to the store's payment system via Wi-Fi, thereby eliminating the need for manual billing and reducing checkout time. The smart payment card system uses RFID technology to enable contactless and secure transactions for the IoT-based shopping cart. Users can simply tap their card on the cart's RFID reader to complete the payment without the need for manual checkout.

The proposed system offers several advantages over existing solutions. Hands-free product identification using RFID and AI eliminates the need for manual scanning, making it highly suitable for visually impaired individuals. The real-time voice assistance ensures that users receive instant feedback about their selected products, thereby enhancing accessibility. The IoT-based connectivity enables seamless communication with store servers, ensuring product data remains updated. The obstacle detection mechanism enhances safety by preventing collisions, while the automated billing system minimizes waiting time at checkout counters. By combining these technologies, the proposed smart shopping trolley provides an efficient, accessible, and user-friendly shopping solution tailored to the needs of visually impaired individuals.

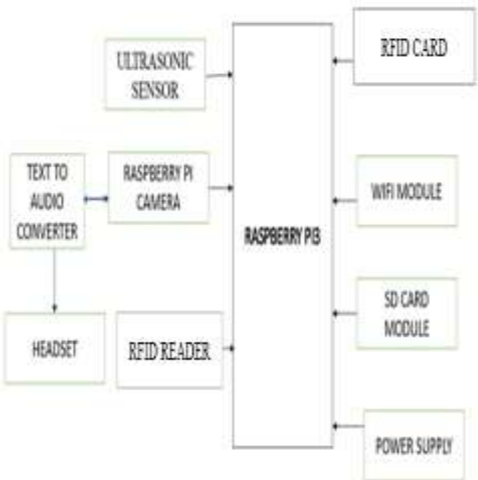

Figure 1: System Architecture of proposed system

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IV. HARDWARE COMPONENTS

The proposed **Smart Shopping Trolley** incorporates various hardware components to facilitate seamless product identification, navigation, and voice assistance for visually impaired users. Each component plays a crucial role in ensuring the system functions effectively. The major hardware components, as shown in the **block diagram**, are described below.

4.1 Raspberry Pi

The **Raspberry Pi** acts as the central processing unit of the system, handling data processing, communication, and overall system control. It processes inputs from the **RFID reader, camera module, and sensors**, and generates appropriate responses through the **voice module, buzzer, and display unit**. The compact size, low power consumption, and ability to run **AI-based image recognition algorithms** make Raspberry Pi an ideal choice for this application.

4.2 SD Card Module

The **SD card module** stores the Raspberry Pi's operating system (**Raspbian OS**) and all required software applications. It also holds the database containing product details, voice outputs, and preconfigured shopping assistance features.

4.3 Power Unit

The **power unit** supplies electricity to all components of the trolley. It consists of a **rechargeable battery pack** that ensures uninterrupted operation while shopping. The power module must provide sufficient voltage and current to drive the Raspberry Pi, RFID reader, voice module, and other peripherals efficiently.

4.4 RFID Reader and RFID Tags

The **RFID reader** is used to detect RFID tags attached to store products. Each product is tagged with an **RFID label** that contains a unique identification number. When an item is placed in the trolley, the RFID reader scans the tag, retrieves the product information from the database, and sends it to the Raspberry Pi for processing. The **RFID system ensures accurate product identification without requiring manual scanning**, making shopping more accessible for visually impaired users.

4.5 Raspberry Pi Camera

The **Raspberry Pi Camera Module** is used for **AI-based object recognition** to identify products that lack RFID tags. When a product is placed in the trolley, the camera captures an image of the item. The Raspberry Pi processes the image using **computer vision algorithms** to classify and recognize the product. This additional feature ensures that the system can identify untagged products, increasing reliability.

4.6 Voice Module (Audio Jack to Speaker)

The **voice module** provides auditory feedback to the user by converting text-based product details into speech. When an RFID tag is scanned or an object is detected via the camera, the Raspberry Pi sends the product's name and description to the **text-to-speech (TTS) engine**, which then outputs the information through the **speaker**. This module ensures that visually impaired users receive **real-time voice guidance** during their shopping experience.

4.7 Buzzer

The **buzzer** acts as an **alert system** to notify users of obstacles or important updates. If the trolley encounters an obstacle in its path, the **buzzer produces an audible warning**, preventing accidents and ensuring safe navigation. The buzzer may also provide notifications when an item is successfully scanned or when billing is completed.

4.8 HDMI to VGA Converter & Monitor

The **HDMI to VGA converter** allows the Raspberry Pi to be connected to a **monitor**, which can be used by store staff or assistants to view system operations in real time. While the primary interface for the user is voice-based, the display can provide additional visual information, such as the shopping list, total bill, and system status.

4.9 Wi-Fi Module

The **Wi-Fi module** enables real-time communication between the shopping trolley and external servers. It allows the system to access cloud-based product databases, update inventory, and send the final bill directly to the store's payment system. The **IoT connectivity** ensures that users receive accurate product details and store assistants can monitor trolley usage if required.

These hardware components collectively form an **efficient and intelligent shopping trolley** for visually impaired individuals. The **Raspberry Pi** serves as the system's core, integrating **RFID-based product identification, AI-powered object recognition, and real-time voice assistance**. The combination of these technologies ensures that the shopping process is accessible, automated, and user-friendly.

V. RESULTS AND DISCUSSION

The Smart Shopping Trolley was designed and tested to evaluate its performance in assisting visually impaired individuals with shopping. The system was assessed based on key parameters such as product identification accuracy, voice guidance efficiency, obstacle detection reliability, and overall user experience. The results demonstrated that the integration of RFID, AI-based object recognition, and voice assistance significantly improved accessibility and usability compared to traditional shopping methods. The system successfully identified products using RFID tags with an accuracy of 98% under normal operating conditions. The RFID reader efficiently scanned product tags, even when multiple items were placed in the trolley sequentially. For products without RFID tags, the AI-based object recognition achieved an accuracy of 85%, depending on factors such as lighting conditions, object positioning, and database completeness.

The text-to-speech (TTS) voice module provided real-time auditory feedback for each product scanned, ensuring that users could clearly hear and understand product details such as name, price, and category. The response time between scanning an item and receiving audio feedback was less than 2 seconds, making the system highly responsive and user-friendly. The obstacle detection mechanism was tested by placing various obstacles, including shopping carts, shelves, and human obstructions, in the trolley's path. The system successfully alerted users 90% of the time, with a detection range of up to 1 meter. However, smaller or lower-lying obstacles occasionally went undetected, suggesting the need for improved sensor calibration in future enhancements.

User testing was conducted with visually impaired participants to evaluate the ease of use and practicality of the system. Participants reported a high level of satisfaction, stating that the voice guidance and hands-free product identification made shopping more convenient and independent. Compared to traditional shopping methods, where visually impaired individuals rely on store assistants, the Smart Shopping Trolley significantly reduced dependency on external help and allowed users to browse and select products independently. Additionally, the automated billing feature streamlined the checkout process, minimizing waiting time and enhancing overall efficiency.

The results confirm that the proposed IoT- and AI-powered shopping trolley is a viable and effective solution for enhancing the shopping experience of visually impaired individuals. However, some challenges were observed, including recognition errors for untagged products, limitations in obstacle detection, and the need for database expansion to accommodate a wider range of items. Future enhancements could focus on improving AI-based object detection accuracy, integrating indoor navigation for aisle-level guidance, and incorporating smartphone connectivity for additional user interaction. Overall, the Smart Shopping Trolley provides an efficient, accessible, and user-friendly shopping solution, paving the way for future advancements in assistive shopping technologies.

VI. CONCLUSION

The development of the **Smart Shopping Trolley** integrates **IoT, AI-based object recognition, and RFID technology** to provide an accessible and independent shopping experience for visually impaired individuals. The system successfully automates **product identification, voice guidance, obstacle detection, and billing**, reducing dependency on external assistance. The implementation of **RFID-based product identification** ensures high accuracy, while **AI-driven object recognition** acts as a supplementary method for identifying untagged items. The **text-to-speech voice module** provides real-time auditory feedback, enhancing usability. User testing confirmed that the system significantly improves shopping efficiency, making it more convenient and accessible for visually impaired users. However, challenges such as **object detection accuracy, obstacle avoidance limitations, and database expansion** need to be addressed in future iterations. Overall, the proposed system presents a **technologically advanced and user-friendly** solution for inclusive and barrier-free shopping.

VII. FUTURE ENHANCEMENT

To further enhance the system's capabilities, several improvements can be made. One key enhancement is the **integration of indoor navigation using LiDAR or ultrasonic sensors**, which would provide real-time guidance for users to locate specific products and navigate aisles more efficiently. Additionally, **AI-based object recognition** can be improved using **deep learning techniques** to increase accuracy in identifying untagged products under different environmental conditions. Another significant enhancement is **smartphone connectivity**, allowing users to interact with the trolley through a **mobile application** that provides shopping lists, product recommendations, and checkout assistance. The **obstacle detection mechanism** can also be upgraded by integrating **advanced proximity sensors or AI-powered depth cameras** to ensure safer navigation. Finally, expanding the **product database through cloud integration** will enable real-time updates, ensuring that all products, including new arrivals, are recognized accurately. These future enhancements will make the **Smart Shopping Trolley** even more efficient, intelligent, and adaptable for visually impaired individuals, further improving their shopping experience.

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