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Autonomous Following and Repositioning Shopping Cart

Dr. Joly M[1], Alwin C K[2], Abhiram K[3], Krishnadas P D[4], Midhul Krishna M M[5]
[1,2,3,4] *B.Tech Student,* [5]*Professor, EEE Department, Universal Engineering College, Thrissur, Kerala*

Abstract: ***The present-day retail market demands the implementation of automation technologies that provide convenience and efficiency in shopping. This paper focuses on the design and development of an intelligent smart shopping cart that is capable of autonomously tracking the user and implementing the feature of self-billing. The system utilizes the Bluetooth Low Energy (BLE) signals transmitted from the customer's smartphone to estimate the relative position of the user using the Received Signal Strength Indicator (RSSI) technique. The system utilizes the ESP32 module to process the signals and move the shopping cart using DC motors connected to a motor driver module. The system also utilizes ultrasonic sensors for real-time obstacle detection. Moreover, the system provides the facility of billing using an Android-based application and Firebase cloud database. The proposed system reduces the manual effort and the long queue at the billing counter, providing an efficient shopping experience.***
Keywords: Smart trolley, BLE tracking, ESP32, autonomous shopping cart/trolley, IoT retail automation, self-billing system.

I. INTRODUCTION

The rapid development of Internet of Things (IoT) and embedded system technologies has greatly influenced the retail shopping environment. Despite the advantages offered by the Internet of Things, traditional shopping carts are still manually operated, requiring the user to physically push the cart around the store. This is inconvenient, especially for elderly people and physically challenged persons. This traditional method does not meet the growing need for smart retail shopping. Inefficiency is another challenge that faces traditional retail shopping. This is due to the inefficiency of the traditional billing system. This system requires customers to spend time queuing at the billing counter. Despite the development of efficient billing systems using Internet of Things, the proposed system either increases the cost of the system or is not compatible with an autonomous mobility system. This is, therefore, another challenge that faces retail shopping. In an attempt to solve the above challenges, this paper proposes an autonomous smart shopping trolley system. This system will track the user using Bluetooth Low Energy (BLE) technology. This system will track the user's position using the Received Signal Strength Indicator (RSSI) values. The system will then move the shopping cart using an ESP32 microcontroller. The system will also employ ultrasonic sensors to detect obstacles during navigation. In addition, the system will employ an Android application that will allow customers to scan their shopping products using barcode scanning. This will eliminate the need for traditional billing counters. This system is efficient, affordable, and user-friendly.

II. LITERATURE SURVEY

The recent advancements in smart retail systems have been directed towards minimizing billing times, enhancing user experience, and increasing automation through the use of IoT.

A recent research paper by Shahroz et al. proposed a smart shopping cart using IoT with RFID for automatic scanning and billing. The system helps in reducing the overall queue times. However, the overall cost of implementation is high due to the need for RFID tags on all products. Another research paper by Seshagopal et al. proposed a smart trolley using RFID for automatic billing and inventory management. Though the system helps in increasing efficiency, the overall implementation cost is high since users need to keep the products close to the RFID tag. Another recent research paper by Anusha et al. proposed a smart shopping cart using IoT with a mobile application for automatic billing. The overall system helps in increasing user experience. However, the overall system does not have the ability to follow the user, which is a prerequisite for automation.

Muralidharan et al. proposed a smart shopping trolley system using IoT and wireless communication technologies, targeting issues like congestion in supermarkets. The proposed system is mainly focused on billing and customer convenience, without incorporating intelligent movement and obstacle avoidance techniques.

In another study, Ranjitha et al. proposed an automated shopping trolley system, focusing on cost-effective design and embedded systems. However, the proposed system does not utilize effective tracking techniques like BLE-based localization and real-time decision-making.

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In recent research, BLE-based localization and RSSI-based tracking techniques are also being used for effective tracking. It has been observed in research studies that the RSSI-based system is effective for proximity detection. However, the change in signals and noise is still a major issue in these systems.

III.PROPOSED SYSTEM

The proposed system is an intelligent autonomous shopping trolley, which is aimed at providing greater convenience and minimizing manual intervention for users in a retail setting. The proposed system includes several subsystems to make the operation smooth and efficient. The Fig.1 shows the block diagram of proposed system.

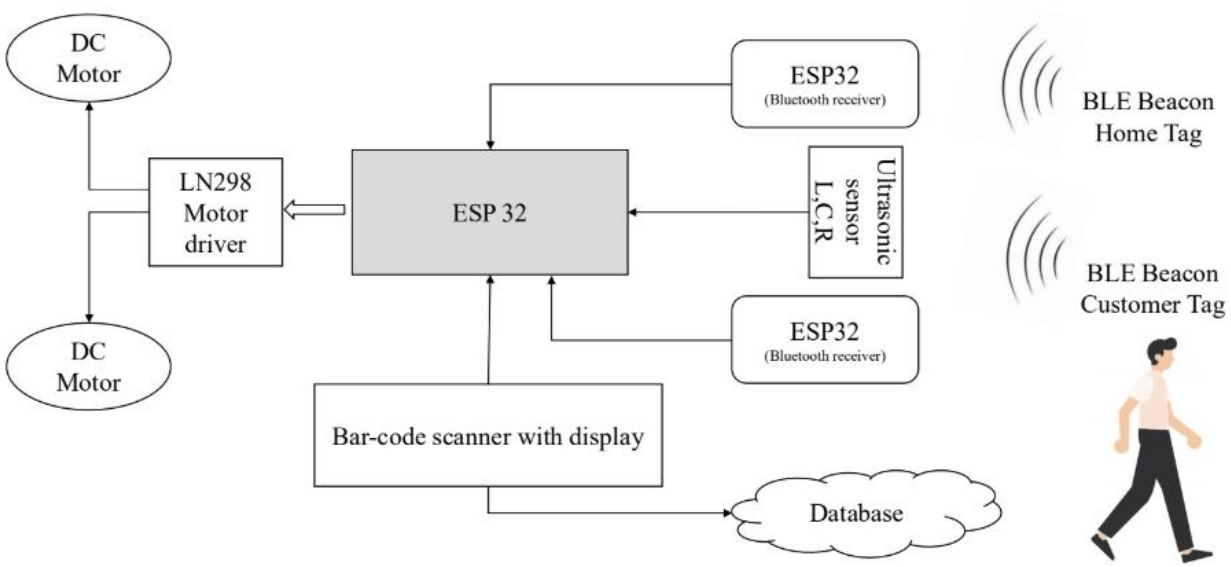


Fig.1 Proposed System

The system will comprise the following main components:

- BLE-Based Tracking Unit: This will enable the localization of the user in real-time using the signal strength of a BLE beacon carried by the user. This will enable the shopping trolley to autonomously follow the user.
- Obstacle Avoidance System: This will provide efficient and safe navigation of the shopping trolley by detecting obstacles in the path of the trolley and taking necessary measures to avoid them.
- Motor Control Unit: This will provide efficient and effortless movement of the shopping trolley by executing the necessary navigation commands and moving the motors in the desired directions: forward, left, right, and stop.
- Android-Based Billing Application: This will provide efficient and effortless management of products and billing, enhancing the shopping experience.

A. Working Principle

The system works on the principle of tracking Bluetooth Low Energy signals. The customer will be carrying a Bluetooth Low Energy beacon, which can either be an ESP32 module or a smartphone transmitting a unique MAC address.

The trolley will be tracking this predefined MAC address by using Bluetooth Low Energy receivers. There will be two ESP32-based Bluetooth Low Energy receivers located on both sides of the trolley to simultaneously measure the Received Signal Strength Indicator (RSSI) values.

Depending on the difference in the RSSI values, the system will be able to identify the relative position of the customer and will send signals to the motor driver to enable the trolley to move in a specific direction.

B. Direction Detection Logic

The direction of the user is calculated by conducting a comparative study of the RSSI signals from the left and right sides of the user using the BLE receivers.

The logic for the decision-making process is as follows:

- If RSSI (Left) > RSSI (Right) → User is moving in the right direction → Trolley moves in the right direction
- If RSSI (Right) > RSSI (Left) → User is moving in the left direction → Trolley moves in the left direction
- If RSSI (Left) and RSSI (Right) are both strong → User is ahead → Trolley moves forward
- If RSSI (Left) and RSSI (Right) are both weak → User is far or lost → Trolley stops

C. Obstacle Avoidance

To ensure safety, the system uses a mechanism for obstacle avoidance. This mechanism uses ultrasonic sensors to continuously scan the surroundings. These sensors then calculate the distance from the obstacles.

- If there is an obstacle in the path of the trolley, it immediately stops
- If there is an obstacle on either side, the direction of the trolley is changed accordingly

The obstacle avoidance feature is given more importance than the user-following feature.

D. Hardware Components

The system relies on robust hardware components for optimal real-time performance. The key components include:

1) ESP32 Microcontroller: ESP32 microcontroller acts as a central processing unit of the entire system. The microcontroller is used for managing the BLE communication, calculating the RSSI values for localizing the user, and executing the control algorithms for navigation. The ESP32 Microcontroller is shown in Fig.2.



Fig.2 ESP32 Microcontroller

2) Ultrasonic Sensors: Ultrasonic sensors are used for detecting obstacles during the movement of the trolley. The ultrasonic sensors measure the distance of the nearby objects by transmitting ultrasonic waves and calculating the time of echo. This helps ensure the safe movement of the trolley. The Ultrasonic Sensors is shown in Fig.3.



Fig.3 Ultrasonic Sensors

3) L298N Motor Driver: The motor driver module is used for controlling the direction of the DC motors. The module is based on an H-bridge configuration, allowing for precise movement of the trolley. The L298N Motor Driver is shown in Fig.4.

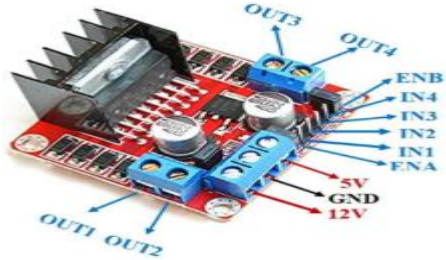


Fig.4 L298N Motor Driver

4) DC Gear Motors (12V, 100 RPM): The DC gear motors are used for providing movement to the trolley. The gear motor provides high torque, which is required for the smooth movement of the trolley. The DC Gear Motors is shown in Fig.5.



Fig.5 DC Gear Motors

5) Battery and Buck Converter: The battery is used as a power source for the entire system. The buck converter module is used for converting the voltage level of the battery according to the requirements of the individual components.The Battery and Buck Converter is shown in Fig.6.





Fig.6 Battery and Buck Converter

E. Billing System

The billing system will be developed in the form of a mobile application using Android Studio with Kotlin as the programming language and Firebase as the real-time database management system.

The major features include:

1) Barcode Scanning: Products will be scanned using the camera of the mobile device.
2) Real-Time Cart Updates: Products will be added to the user's cart in real-time using Firebase.
3) Automatic Bill Calculation: The bill will be calculated in real-time as products are added or removed.

F. Advantages of the Proposed System

The proposed system of an autonomous shopping trolley has several advantages:

1) Hands-Free Shopping Experience: This system facilitates the customer to move freely without having to physically push the trolley, thus providing a high degree of convenience.
2) Reduced Billing Queues: This system is integrated with an Android-based billing system, reducing the time spent in billing queues.
3) User-Friendly and Accessible: This system is designed to cater to the needs of elderly and physically challenged people, providing them a high degree of comfort while shopping.
4) Low-Cost Implementation: This system is implemented using cost-effective hardware, making it economically viable for real-world applications.
5) Scalable for Real-World Deployment: This system is designed in a way that it can be easily extended to support other technologies like IoT and AI.

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IV. RESULTS AND DISCUSSION

The developed prototype of the autonomous shopping trolley system was successfully implemented in a controlled indoor environment. The experimental results show the efficency and reliability of the proposed system.

The system was able to successfully implement accurate human-following behaviour using BLE-based RSSI measurements. The system was able to maintain a reasonable distance and direction with respect to the user.

The obstacle avoidance mechanism was also found to be efficient in this proposed system. The ultrasonic sensors were able to detect obstacles in real-time and take the required actions to avoid them.

The motor control unit was also found to be efficient in this proposed system. The ESP32 was able to integrate with the motor driver successfully and provide accurate directional control to the system. The system was able to move forward, turn, and stop seamlessly using this mechanism.



Fig.6 Final Prototype of the Autonomous BLE-Based Smart Shopping Trolley

In addition to this, the Android-based billing application was also found to be effective in this proposed system. The application was able to reduce the time required in bill generation and provided accurate product management.

The system was found to be performing optimally in an indoor environment where BLE signals were found to be more stable. However, minor changes in RSSI values were found in this proposed system due to environmental factors like obstacles, reflections, and interference. This may affect the accuracy of the system to a certain degree. However, this issue can be resolved using filtering techniques like moving average or Kalman filtering.

The proposed system was found to be efficient and reliable in this experiment and is likely to improve in terms of accuracy in the near future.

V. CONCLUSIONS

This paper has discussed the design and implementation of a BLE-based autonomous shopping trolley system for billing purposes. The proposed system has efficiently utilized IoT technology, embedded systems, and mobile application development to enhance the overall shopping experience.

The proposed system has successfully implemented a reliable human following capability, efficient obstacle avoidance mechanism, smooth navigation, and a billing system. These features can efficiently reduce manual effort and enhance overall efficiency.

Moreover, the proposed system has also been found to be cost-effective, scalable, and suitable for deployment in a real-world environment. With further advancements in localization accuracy and automation techniques, this proposed system has strong potential to contribute to future smart retail technology.

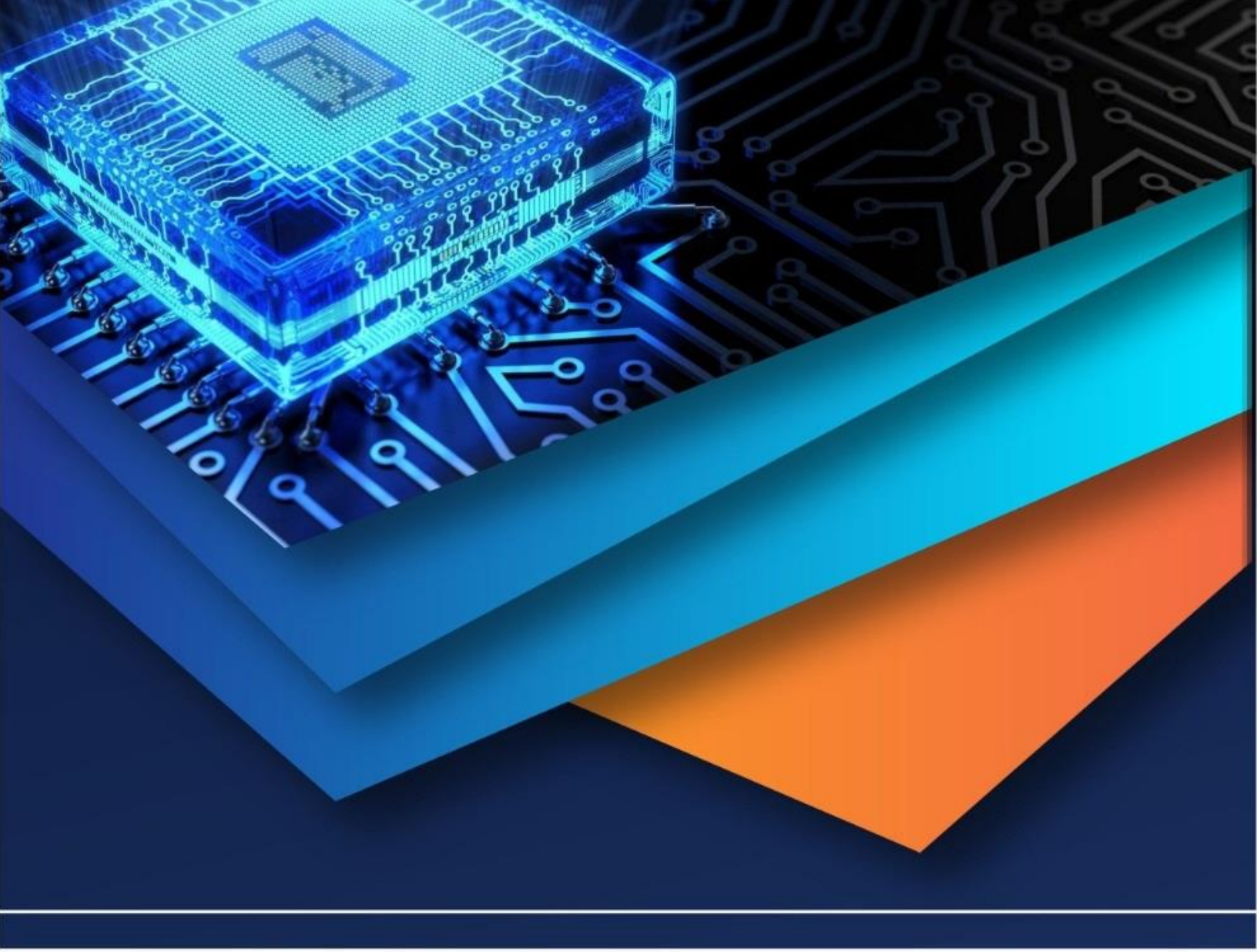
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