Smart Shopping Cart

Task 6.1P – Project Pitch
SIT210 – Embedded Systems Development

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Problem Statement

In the current fast-paced society, retail stores and supermarkets are still patterned with a high volume of manual billing and checkout of goods, which require barcode scanning. Customers wait in long lines as the cashier manually scans each reasonably-sized item. This is time consuming and often leads to human errors, incorrect bill amounts, and customer disappointment, particularly during busy times.

Some larger retailers have begun to incorporate semi-automated or self-checkout options, which can sometimes be complicated for novice users of the system, bewildering for older customers, and still requires human oversight. They are also greatly expensive to implement and maintain, so are often less ideal for smaller stores. The other major area of concern is lack of accessibility and inclusivity. An aging or differently-able customer who purchases groceries can have a difficult time pushing even a half-full, heavy shopping cart through any crowded store's aisles. Existing, traditional trolleys provide no type of mobility assistance or smart guidance for someone with a need for motion assistance.

Existing Systems and Their Limitations

In the current landscape of retail, a majority of supermarkets and grocery stores continue to deploy traditional barcode-based billing systems and physical checkouts. For years, standard barcode-based billing and physical checkouts have dominated the retail experience, but now they are just becoming inefficient in accommodating large customer flows or the convenience experience of shoppers.

Traditional Barcode-Based Billing Systems

- Extremely time-consuming, especially during peak shopping hours.
- Requires manual intervention — increasing labor cost.

Self-Checkout Kiosks

- Expensive to install and maintain.
- Requires constant supervision by store staff to prevent misuse.

Amazon Dash-Cart

- Very high setup cost
- Requires constant internet connectivity and technical maintenance.

Gaps and Opportunities

Even though modern supermarkets are beginning to incorporate digital billing and barcode scanning technologies, most of the current instances of these technologies still rely on human transactions and attention to detail. Self-scan kiosks and barcode-based smart carts include a requirement to scan barcodes for items, which can be tedious and error-prone. Furthermore, these types of systems are costly and not intuitive for older customers or shoppers with physical limitations.

This creates a clear opportunity in the market for a cost-effective, fully automated solution that can help customers throughout their shopping journey. This is an opportunity to create an IoT-enabled, sensor-based smart cart that can autonomously identify items, follow the user, keep a running total of the bill, and facilitate a secure payment method without asking for external assistance.

Proposed Solution

The Smart Shopping Cart with Central Billing and Motion Assistance is an Internet of Things based embedded system that will change the way people shop by including automated billing, better mobility for the user and reduced human roles in the checkout process. The automated shopping solution is based on embedded systems, includes the ESP32 based smart cart to detect products, apply the billing, and the motorized system to aid mobility; as the Raspberry Pi that will serve as billing engine. All communication is wireless using MQTT, so every scanned item will be up to date.

Smart Cart Unit (ESP32)

This is the cart's main smart unit. It uses RFID tags to locate your items, weighs them to confirm accuracy, and shows your total as you check out as you shop. It also provides instant visual and sound alerts to the shopper using screens and lights.

Moving Cart System

This part makes the cart move, mostly on its own. There are sensors so it doesn't bump into objects, plus some controls for the wheels. Allowing the cart to automatically stop when the user halts or manually pause movement using a control button.

Central Billing System (Raspberry Pi 4)

This is the primary computer system. It collects data from all smart carts in the store, keeps track of every item, calculates a final bill for the user, and handles the checkout process through touchscreen.

Hardware Modules

Smart Cart Unit

Hardware Parts:

- ESP 32 : Main brain of the system
- RFID scanner and tags : Detects the UID of each product.
- Load sensor: Verifies the physical presence.
- 16X2 LCD display: Displays the info.
- 18650 Li-ion Batteries (x3) + TP4056 Charging Module: Powers the entire unit. The charging module allows easy USB recharging.

Moving Cart Subsystem

Hardware Parts:

- BO Motors (x4): Helps in the movement Of the cart.
- Ultrasonic sensor: Detects the obstacles.
- Encoder disc and sensor: to measure motor speed and distance accurately.
- Wheels

Central Billing System

Hardware Parts:

- Raspberry Pi 4: Acts as a mini-server handling billing logic and communication.
- Micro SD Card (32GB)
- USB-C Power Adapter
- Touchscreen Display

Working of the System

1

Start

The smart cart turns on when the main power switch is turned on and the system initializes, the user scans their RFID tag to authenticate and activate the cart. Following activation, the cart follows the user automatically by using the ultrasonic sensors to keep a distance behind the user. The cart will stop if the user stops .

2

Scan and Check Item

When a customer puts an item in the cart, an RFID scanner reads its tag and gets the price. A weight sensor confirms the item is there and helps prevent theft. The cart's screen then shows the item details and the updated total bill.

3

Live Bill Updates

The cart's computer quickly updates the bill on the screen. This bill data is sent wirelessly to the main store computer to keep records.

4

Store Monitoring

The main store computer gets shopping data from all active carts and updates the main store dashboard. Staff can see total sales, where carts are, and stock levels in real-time.

5

Pay at Checkout

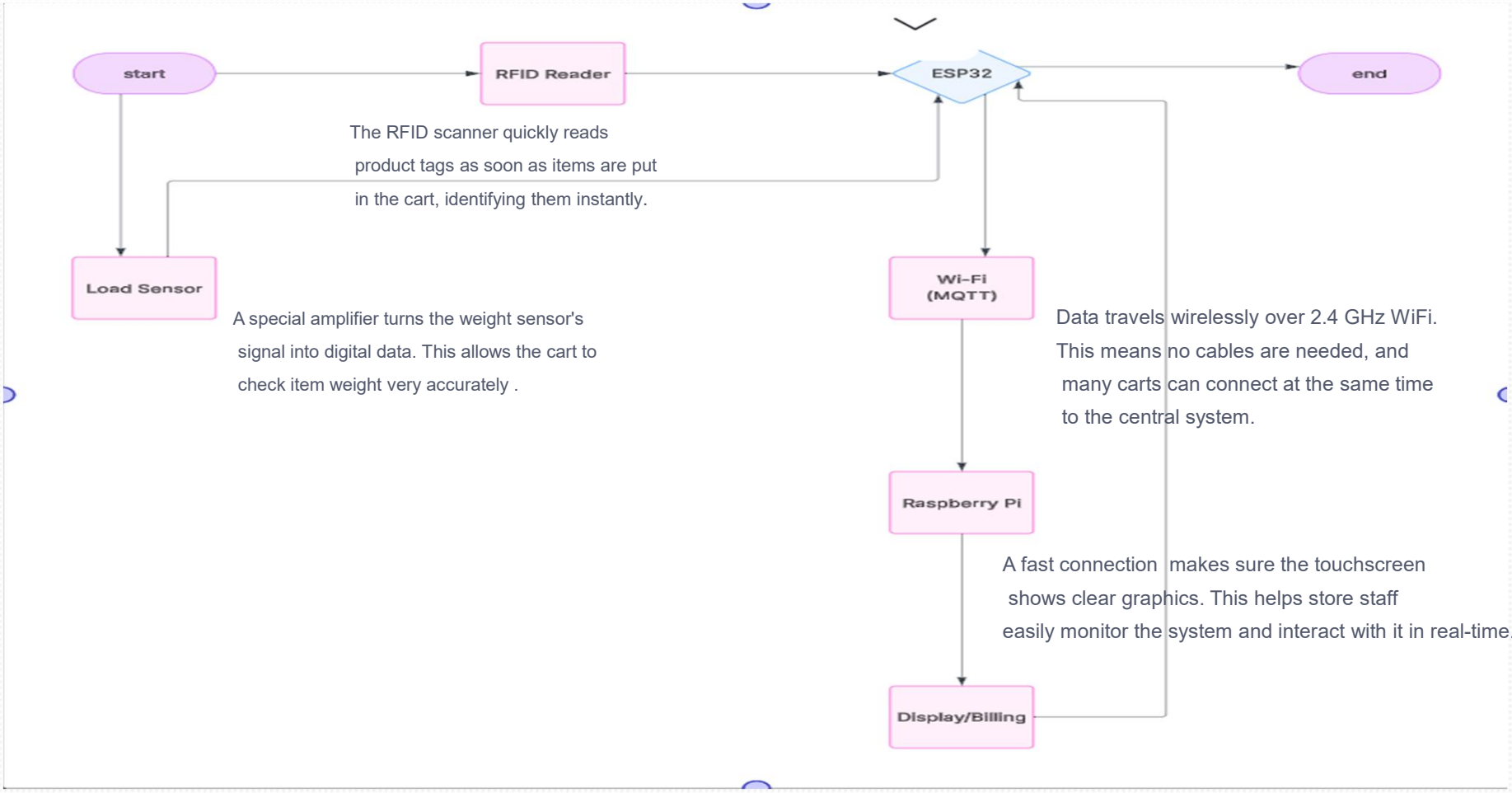
At the checkout, the final bill appears on the touchscreen. After successful payment, the main store computer sends a signal to unlock the specific cart.

6

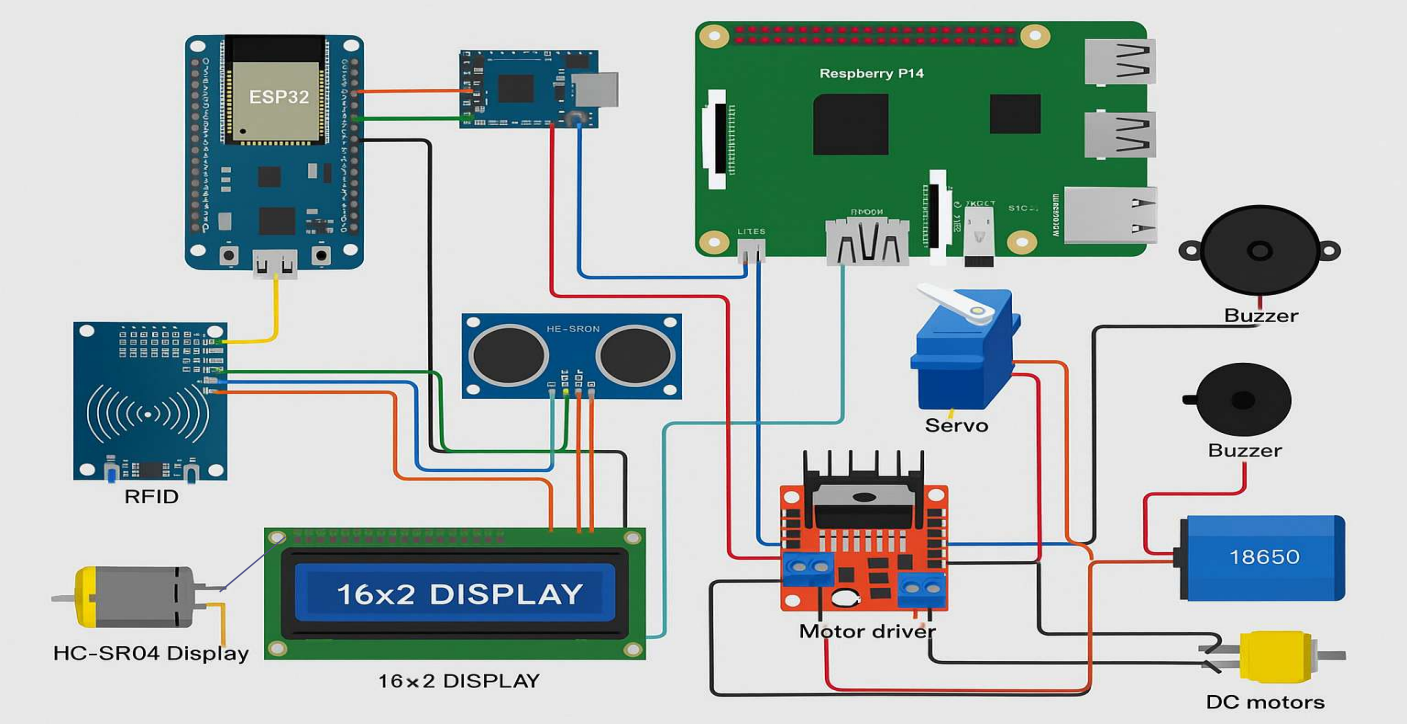
Cart Unlocks and Returns

A small motor unlocks the cart. The cart can then use its motor system to move to the exit.

How Components Talk to Each Other



Circuit Diagram



Expected Impacts

The Smart Shopping Cart with Integrated Payment and Movement Estimates is anticipated to have significant implications for customer experience and the retail environment. Through the integration of automation, IoT, and embedded control, the system is providing practical solutions.

Social Impact

- Improves access for senior and differently-abled customers through mobility assistance and guide shopping.
- Reduces embodiments on physically challenged and makes shopping available for all.
- Encourages digital literacy of consumer by embedding user-friendly technology within a seamlessly used daily basis.

Economic Impact

- reduces the amount of manual labor or checkout staff, which lowers operational costs for store owners.
- Will improve speed and efficiency of checkout, meaning more customers can be served in less time.
- Reduces theft and billing errors, leading to better profit margins.

Environmental Impact

- Minimizes paper bill usage with digital or on-screen billing.
- Advocates energy-efficient embedded design utilizes low power sensors and rechargeable Li-ion batteries.
- Encourages sustainable retail with reusable RFID tags.

Smart Features and Future scope

Smart, Two-Part Brains

A small computer in each cart gives instant updates, while a main computer handles bigger tasks like tracking all carts. This makes the system quick and easy to grow.

Automated mechanism

The shopping cart features an automatic following function using an ultrasonic distance sensor to keep a fixed distance from the user. Slight accelerations allow consumable following ability and stopping when the user stops and starts walking again when they start walking. This removes the need for the user to manually pull or push the shopping cart, allowing for a completely hands-free shopping experience.

User Authentication and security

Before using the cart, the user must scan a unique RFID card, ensuring that each cart is securely assigned to one customer. The cart includes an e stop button that allows users to pause or resume movement manually.
The servo motor lock ensures that the cart remains stationary until billing is completed or payment is confirmed.

Centralized payment

At the end of shopping, the user simply walks to the checkout. The Raspberry Pi submits the total bill to the central system, which facilitates rapid payment, and automatically unlocks the cart once the bill is confirmed.

Mobile integration

An exclusive mobile app can be built to connect to the cart via Wi-Fi or Bluetooth. This app would show users their real-time cart total, provide a summary of what they have purchased, and allow users to pay digitally from their customer's phone.

Voice control

To enhance accessibility for seniors and physically challenged individuals, the cart could incorporate voice recognition and gesture sensors. Users could control the cart through voice commands such as "stop," "follow," or "return," which would eliminate the need for pressing any buttons, thereby enhancing the user experience and access.

A-I based navigation

AI algorithms can be used to allow the cart to move about the aisles of the store on its own. with computer vision or LIDAR-based mapping, the cart could detect obstructions, plan alternate routes, and even navigate users to precise locations of desired products in busy stores for safety and increasing time efficiencies.

Solar Powered design

Future carts could have compact solar panels or advanced power management circuits as a way to improve battery life. The system will be more sustainable, reduce dependency on constant charging, and be an eco-friendly smart retail technology..

Evaluation

- Functionality Testing

Every module tested individually for functionality, including the RFID Scanner, Load Sensor, Ultrasonic, and Motor Driver, then put together as a fully integrated system. The system will accurately detected products with RFID, calculating total weight with the load sensor, and communicated real-time data to the central billing unit.

- Responsiveness and Real-Time Operation

The cart responded to user movement using the ultrasonic sensor. Users changed their position, and the cart was able to keep a consistent distance of 30-40 cm. The cart would react in 1 seconds for user motion changes.

- Robustness and Fault Tolerance

Testing for robustness involved simulating various situations including a brief interruption in the Wi-Fi network, sudden power reset, and the application of noise from the a sensor. The system will successfully automatically reconnected to the network and collected all data without any issues.

- Power Efficiency and Battery Performance

The DC-DC converter and TP4056 module will be monitored to ensure stable voltage regulation and safe recharging. The ESP32's low-power mode is expected to extend the battery life when the system is idle.

- System Reliability

The cart should stop as soon as the user presses the button or is obstructed. We will test the servo lock mechanism to check proper lock and unlock during the billing process.