International Journal of Emerging Science and Engineering (IJESE)
ISSN: 2319–6378 (Online), Volume-14 Issue-7, June 2026

RFID-Based Smart Trolley System

Aparna S Kumar, Mevin Kurian, Midhun Venu, Sanjay Sajan, Silpanjali Gopal

***Abstract**: The project in this paper focuses on a smart shopping trolley that utilizes human following technology to track and identify the user within a shopping area. In this case, the user carries a tag in the form of a wristband or a card, and the shopping trolley carries a reader that identifies the user. The reader then tracks the user using RFID technology. However, to ensure smooth tracking and safety, the shopping trolley uses a microcontroller to integrate RFID with short-range sensors, providing continuous distance measurements. In this case, the shopping trolley maintains a safe distance from the user. In addition, the shopping trolley can track items and link them to the user's identification. In this paper, the shopping trolley tests human-following technology in a simulated shopping area. The results show that the shopping trolley performs perfectly in following the user and providing convenience in shopping. Moreover, the paper discusses the limitations of using RFID technology for localisation and proposes a solution.*

Keywords: RFID, Human Following, Autonomous Shopping Trolley, PID Control, Obstacle Avoidance.

Nomenclature:
RFID: Radio Frequency Identification
LCD: Liquid Crystal Display
SMPS: Switch-mode Power Supply
RF: Radio frequency

I. INTRODUCTION

Retail, as a global industry, has been changing rapidly due to technology and e-commerce. As shopping malls and supermarkets continue to see football traffic decline, they must find ways to improve the customer experience. While traditional shopping carts serve their purpose, the physical exertion of using them and the inconveniences they pose (especially for seniors, disabled individuals, or people who buy many items) are drawbacks.

Smart solutions like the Human-Following Shopping Trolley System help address these concerns by leveraging advances in robotics, sensors, and automation. The Human-Following Shopping Trolley System addresses these issues by employing developed automatons and personalised automation protocols. The system consists of an intelligent shopping cart that leverages advanced sensors, actuators, and connectivity options to follow shoppers autonomously. It also integrates a mobile application which shoppers can use to interact with the cart and manage their shopping ride. The successful melding of mobile applications and IoT technology in the retail space will provide a shopping experience that is both easier than traditional shopping and more personalised.

Manuscript received on 25 March 2026 | First Revised Manuscript received on 08 May 2026 | Second Revised Manuscript received on 20 May 2026 | Manuscript Accepted on 15 June 2026 | Manuscript published on 30 June 2026.
*Correspondence Author(s)
Aparna S Kumar, Department of Electrical and Electronics Engineering, Mangalam College of Engineering, Ettumanoor, Kottayam (Kerala), India. Email ID: aparnaskumar0104@gmail.com, ORCID ID: 0009-0007-7134-2146
Mevin Kurian, Department of Electrical and Electronics Engineering, Mangalam College of Engineering, Ettumanoor, Kottayam (Kerala), India. Email ID: mevinkurian398@gmail.com, ORCID ID: 0009-0000-9650-258X
Midhun Venu*, Department of Electrical and Electronics Engineering, Mangalam College of Engineering, Ettumanoor, Kottayam (Kerala), India. Email ID: midhunvenu04@gmail.com, ORCID ID: 0009-0008-4340-6488
Sanjay Sajan, Department of Electrical and Electronics Engineering, Mangalam College of Engineering, Ettumanoor, Kottayam (Kerala), India. Email ID: sanjaysajan2004@gmail.com, ORCID ID: 0009-0008-2749-772X
Silpanjali Gopal, Department of Electrical and Electronics Engineering, Mangalam College of Engineering, Ettumanoor, Kottayam (Kerala), India. Email ID: silpanjali.gopal@mangalam.in, ORCID ID: 0009-0000-0263-2309

II. OBJECTIVES

A. To design a system which will control the trolley speed according to the speed of the human
B. To design and produce a versatile trolley that is user-friendly for humans and makes their lives more productive.
C. To produce an automatic trolley that can carry heavy things to move from one point to another point

III. PROBLEM STATEMENT

Smart human-assisted shopping carts provide a more streamlined and time-efficient way for shoppers to locate items, check them into the cart and move to the next item without worrying about carrying the cart. Therefore, a consumer can shop more easily, faster, and with less hassle.

Smart human-assisted shopping carts represent a new opportunity for shopping centres to deliver a more tailored and efficient shopping experience. This technology allows consumers to enjoy a totally hands- off shopping experience and allows shopping centres to stand apart from their competitors. As such, smart human-assisted shopping carts will be an important asset for shopping centres to create, retain and grow their customer base over time.

Traditional shopping carts have several limitations that can negatively affect the overall shopping experience, leading to frustration and inconvenience. The following problems demonstrate the issues associated with traditional shopping carts:

Physical Exertion – It can be physically exhausting to push or pull a heavy shopping cart through store aisles, especially for seniors, individuals with mobility issues, or mothers with small children. As a consequence, many may choose to avoid going into stores altogether.

IV. LITERATURE REVIEW

Autonomous robots have long been researched for use in many fields, including human navigation, and assisting humans with vision systems using expensive special algorithms. Some of these algorithms require significant

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processing power and, therefore, can be very expensive to implement. As a result, ultrasonic- and infrared-based approaches have been developed as cost-effective tracking systems for small-scale robotics applications. Human-following robots have been researched in healthcare and logistics settings; however, their application in retail remains very limited. This project seeks to develop a low-cost, practical solution for creating a scalable human-following trolley for use in retail shopping environments.

A. **Quoc Khanh Dang, Young Soo Suh [2012]:** "Human-following robot using infrared camera". In 2012, Quoc Khanh Dang and Young Soo Suh designed a robot that can follow people using an infrared (heat- sensing) camera. This camera helps the robot see and track people even in the dark by detecting their body heat. The robot uses a small computer (microcontroller) to process this information, motors to move around, and a special program to follow the person smoothly.

B. **W. W. Tai, B. Ilias, S.A. Abdul Shukor, N. Abdul Rahim and MA Markom [2019]:** "A Study of Ultrasonic Sensor Capability in Human Following Robot System". A robot with an infrared camera can follow people by sensing their body heat. This helps it see and track them more accurately, even in the dark. It has a small computer to process data, motors to move, and a program that helps it follow smoothly.

C. **Mr Kumar and Mr Gupta,12 December [2017] [2] [4]:** "A Smart Trolley using Arduino". The Smart Trolley is a shopping cart that uses Arduino technology to make shopping easier. It can guide you around the store and keep track of the items you put in it in real time.

D. **D.J.S.P.S. Dhavale Shraddha D [2016] [3]:** IoT-Based Intelligent Trolley for Shopping Mall. An IoT-based intelligent trolley in shopping malls enables real-time item tracking, automated billing, and personalised shopping experiences, enhancing efficiency and customer convenience. An IoT-based smart shopping cart can track items as you shop, automatically generate your bill, and provide a more personalised shopping experience, making shopping faster and easier.

E. **S. M. Kalyani Dawkharet al [2018]:** Using Radio Frequency Identification (RFID) technology, an electronic shopping cart. This cart has a feature to keep track of its contents. This product displays the product name, expiration date, and price on a Liquid Crystal Display (LCD) screen. The trolley only performs the aforementioned tasks, which is a downside of the system. Since the trolley is electronic, the automatic travelling facility is not covered [5].

F. **Hanooja T, Raji C.G and Sreelekha M in the Year of [2020]:** "Human Friendly Smart Trolley with Automatic Billing System". A smart shopping cart with automatic billing makes shopping easier by scanning items as you put them in, showing the total cost right away, and letting you pay without waiting at the checkout. It can also help you find your way in the store, making it simple and convenient to use.

G. **Mr P. Chandrasekar and Ms T. Sangeetha in the Year of [2014]:** "Smart Shopping Cart with Automatic Billing System through RFID and ZigBee". A smart shopping cart uses RFID tags to automatically detect items you add or remove, keeping your bill accurate in real time. This makes shopping faster and easier without manual scanning.

H. **S. K. Shankar, S. Balasubramani, S. A. Basha, S. Ariz Ahamed, and N. S. Kumar Reddy [2021] [1]:** "Smart Trolley for Smart Shopping with an Advanced Billing System using IoT". A smart shopping cart with IoT sensors automatically detects what you put in it and updates your bill instantly, making shopping quicker and easier.

I. **Rahul Sonawane, Abhishek Pandey, Chetan Gorivale, Hrushikesh Surve, Prof. Minal Hardas [2021]: "**Smart Trolley with human follower**".** Many researchers have worked on making shopping easier. Older systems used barcodes, which caused long billing lines. Some projects used RFID tags to automatically scan products and speed up checkout, while others created apps and sensors to guide customers or display discounts. A few even designed trolleys that follow shoppers so they don't have to push them. This paper combines these ideas into a smart trolley that scans items, shows prices, and follows customers, making shopping faster and less tiring.

J. **Digambar Rane, Pratik Lavhate, Nikhil Shinde, and Ravindra Kankate [2022]:** "Follow Me Smart Shopping Trolley". Researchers have developed various smart trolleys that use RFID, barcode scanners, sensors, and wireless communication technologies (Bluetooth, ZigBee, Li-Fi) to automate billing and item tracking. However, most focus only on billing, not on reducing physical effort. This paper introduces a "Follow Me" trolley that both automates billing and follows shoppers, making shopping easier and hands-free.

K. **T. Manikandan, C.S.Balasubramaniam, S. Deepak Kumar, S.Dhanish [2022]: "**A Human Following Trolley". People have been creating robots and trolleys that can follow humans to make shopping easier. Older systems used sensors, Bluetooth apps, and voice controls, but needed a lot of manual effort. Newer designs use cameras and smart sensors to track people more accurately and avoid obstacles. This paper builds a smart human-following trolley that uses sensors and an Arduino, so shoppers don't have to push carts, making shopping simpler and more comfortable.

L. **Gitanjali Jadhav, Pooja Nikam, Aditi Gharge, Prof Prashant Yadav [2024]:** "Hands-Free Smart Shopping Trolley with Human Following Technology". Shopping trolley tech has evolved from basic billing and RFID systems to smart, IoT-powered carts with sensors, cameras, and AI that can follow customers, avoid obstacles, and work hands-free. People have been creating smart shopping trolleys to make shopping easier and faster. Older designs used RFID, barcodes, and IoT to track items and speed up billing. Newer ones use sensors, LiDAR, Bluetooth, and AI so trolleys can follow shoppers, avoid obstacles, and give a smoother experience. This paper examines these ideas and proposes a hands-free trolley that follows customers, tracks items in real time, and automates checkout to save time and help stores manage inventory more effectively.

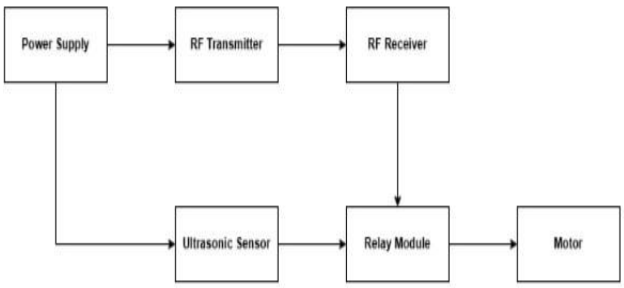
M. **Vivek S. Vaidya, Kaustubh N. Gaigole, Sanket Chamlate, Pruthviraj P. Futan, Mohit N. Deshmukh, Nitin S. Thakare [2025]:** "AI-Powered Smart Shopping Trolley". People have been working on making shopping trolleys smarter and easier to use. Older

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

ISSN: 2319–6378 (Online), Volume-14 Issue-7, June 2026

designs used RFID tags, IoT, and ZigBee to scan products and speed up checkout, while some added sensors and cameras to enable trolleys to follow shoppers. Newer systems use AI and computer vision to track products in real time, avoid obstacles, and even suggest items. This paper builds on those ideas to create a smart AI-powered trolley that scans items, tracks spending, sends alerts, and makes shopping quicker and more convenient.

V. BLOCK DIAGRAM



A. Power Supply

The power supply delivers electrical power to each component of the circuit, including the RF (radio frequency) transmitter, receiver, ultrasonic sensor, relay module, and motor, ensuring each part operates effectively.

B. RF Transmitter

The RF Transmitter is similar to a remote control because it transmits wireless signals from the transmitter to the receiver. When you press a button or transmit a command, the RF transmitter converts the signal into radio frequency. Then, via the antenna, it transmits the signal wirelessly to the RF receiver at the other end.

C. RF Receiver

The RF receiver receives the wireless signal sent by the RF transmitter. The RF receiver decodes the signal and then sends it to the relay module to determine whether the motor should be turned on or off. This is how wireless communication occurs in this system.

D. Ultrasonic Sensor

The ultrasonic sensor acts as the "ears" of the system, much like human ears. When it emits a sound frequency that humans cannot hear, the sensor uses time delays to determine whether anything is in its vicinity and the distance to that object. An example of this is when an object comes within a specific distance of the sensor. In a way, this sensor is the "eyes" of the system, as it detects and sends a signal to turn the motor ON/OFF.

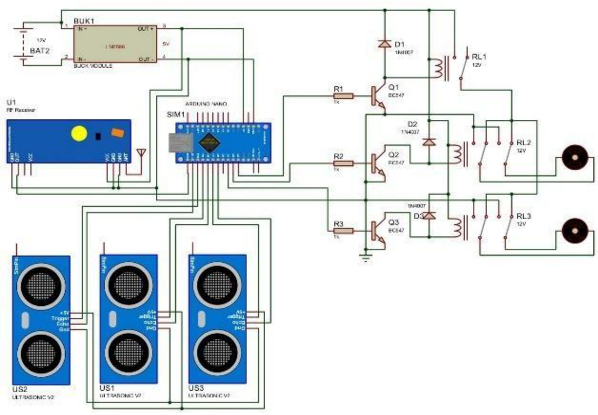
E. Relay Module

The relay module is used as an automatic ON/OFF switch for the system. It receives signals from the ultrasonic sensor and RF receiver. Depending on the input from the ultrasonic sensor and RF, the relay module allows or stops the flow of electricity to the motor. To explain this in simple terms: when the relay is ON, the motor is ON; when the relay is OFF, the motor is OFF.

F. Motor

The motor is the system's output component that performs the task. When the motor receives current through the relay, it will operate (e.g., rotate/fan, open/close a gate, or move a vehicle); however, when the relay is turned OFF, the motor will stop.

VI. SYSTEM ARCHITECTURE



A. System Architecture

To enable it to follow autonomously, the trolley has been equipped with sensors, microcontrollers and actuators. The ultrasonic sensor measures the distance to the user and the trolley, while infrared sensors are used for both line following and obstacle detection. The motor driver connects the microcontroller to the DC motors, allowing control of the trolley's movement.

B. Hardware Components

i. Buck Module

Buck converting is a component in power electronics that reduces a DC voltage (High) to a DC voltage (Low) at an efficient rate, primarily using the switch mode power supply (SMPS), using devices such as transistors, diodes, inductors, and capacitors.

ii. RF Receiver

An RF receiver is a circuit/module that demodulates or decodes a signal at a specific frequency and retrieves the encapsulated data transmitted via radio waves. It represents the terminal involved with communication using radio frequencies.

iii. Arduino Nano

The Arduino Nano is a compact microcontroller board that can be placed on a breadboard. It is part of the Arduino family and is based on a relatively low-cost microcontroller (the ATmega328P chip). The Arduino Nano is designed for applications where physical space is limited, yet it utilises the capabilities of a complete microcontroller.

iv. Ultrasonic Sensor

Ultrasonic sensors measure the distance to an object by sending an ultrasonic pulse and listening for the reflected sound waves. The time it takes for the soundwaves to return is then used to calculate the distance to the target.

v. Mechanical Design

The Mechanical Design of this item is a mesh basket that mounts on a four-wheel-drive robot base. The robot base is used for stability and for transporting heavy loads.

C. Software

Embedded C is used to program the Atmega 328 via the Arduino platform. The software logic includes ultrasonic distance measurement, PID-based motor speed control, and IR sensor line detection algorithms.

D. Working Principle

Using an infrared sensor system, a trolley can follow the distance of its user. The trolley's speed will increase if the user moves away from it. If the user stops moving, the trolley will also stop. IR sensors enable safe, dependable, and hands-free operation of a trolley.

VII. METHODOLOGY

A. Identifying the Problem and Goal

Pushing heavy shopping carts can be exhausting at the supermarket.

The purpose of this project is to design a smart cart that will carry an individual's items and autonomously track the person during a shopping trip.

B. System Design and Component Selection

Three major modules make up the system. Specifically, there is

i. The Human Tracking Module automatically tracks and follows the consumer (user).

ii. The Control and Communication Module, which processes the data.

Additionally, there is also a wide variety of electronic components to ensure compatibility with the system, including: Arduino board; Microcontroller (Microchip Technology); Ultrasonic Sensors; RFID Reader (RC522); DC Gear Motor; Motor Driver (L298N); Battery Unit. These components were selected based on the system's requirements.

C. Human Tracking Implementation

Ultrasonic sensors on the front of the cart form the human-tracking system. Ultrasonic sensors track the distance between the cart and the customer wearing a Radio Frequency (RF) wristband/beacon.

The microcontroller processes distance information and activates the DC motors to keep the cart moving forward, stopping, or turning while maintaining the proper distance from the customer.

Additional sensors have been added to the cart to detect and avoid any potential obstructions.

D. System Testing and Evaluation

Following software programming and hardware assembly, the system is tested for precise person tracking and obstacle avoidance. Dependable data processing and RFID tag detection. Both operational safety and power efficiency.

VIII. ALGORITHM

Step 1: Start the system.
Step 2: Initialize all pins for the ultrasonic sensors, relays, and RF receiver.
Step 3: Set all relays OFF (trolley in stop mode).
Step 4: Continuously check the RF receiver input.

- If RF signal = LOW, keep the trolley stopped.
- If RF signal = HIGH, proceed to sensor scanning.

Step 5: Measure distances from all three ultrasonic sensors (Left, Centre, Right).
Step 6: Compare measured distances with the obstacle threshold
Step 7: Decision-making:

- If **centre distance** > **threshold** → move **forward** (all relays ON).
- Else if **left distance** > **right distance and left** > **threshold → turn left** (Left + Master relays ON).
- Else if **right distance** > **left distance and right** > **threshold → turn right** (Right + Master relays ON).
- Else → **stop** (all relays OFF).

Step 8: Repeat Steps 4–7 continuously. Repeat Steps 4–7 continuously.

IX. PROGRAM CODE

```
int trigLeft = 10; int echoLeft = 11; int trigCenter = 9; int
  echoCenter = 8; int trigRight = 7; int echoRight = 6;
int rfReceiverPin = 12; int relayLeft = 2;
int relayRight = 3; int relayMaster = 4;
const int obstacleThreshold = 20;
long getDistance(int trigPin, int echoPin)
  {digitalWrite(trigPin, LOW); delayMicroseconds(2);
  digitalWrite(trigPin, HIGH); delayMicroseconds(10);
  digitalWrite(trigPin, LOW);
long duration = pulseIn(echoPin, HIGH, 25000); long distance
  = duration * 0.034 / 2;
return distance;
}
void stopTrolley() {digitalWrite(relayLeft, LOW);
  digitalWrite(relayRight, LOW); digitalWrite(relayMaster,
  LOW);
}
void forwardTrolley() {digitalWrite(relayLeft, HIGH);
  digitalWrite(relayRight, HIGH); digitalWrite(relayMaster,
  HIGH);
}
void leftTurn() {digitalWrite(relayLeft, HIGH);
  digitalWrite(relayRight, LOW); digitalWrite(relayMaster,
  HIGH);
}
void rightTurn() {digitalWrite(relayLeft, LOW);
  digitalWrite(relayRight, HIGH); digitalWrite(relayMaster,
  HIGH);
}
void setup () {Serial.begin(9600); pinMode(trigLeft,
  OUTPUT); pinMode(echoLeft, INPUT);
pinMode(trigCenter, OUTPUT); pinMode(echoCenter,
  INPUT); pinMode(trigRight, OUTPUT);
  pinMode(echoRight, INPUT); pinMode(relayLeft,
  OUTPUT); pinMode(relayRight, OUTPUT);
  pinMode(relayMaster, OUTPUT); pinMode(rfReceiverPin,
  INPUT); stopTrolley(); Serial.println("Waiting for RF
  Tag");
}
void loop () {
int rfSignal =
  digitalRead(rfReceiverPin);
  if (rfSignal == HIGH) {
long leftDist =
```


DOI:10.35940/ijese.D4761.14070626
Journal Website: www.ijese.org

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```
  getDistance(trigLeft, echoLeft);
long centerDist = getDistance(trigCenter, echoCenter);
long rightDist = getDistance(trigRight, echoRight);
  Serial.print("L: "); Serial.print(leftDist); Serial.print(" cm | C: "); Serial.print(centerDist); Serial.print(" cm | R: ");
  Serial.println(rightDist);
if (centerDist > obstacleThreshold) {forwardTrolley();
}
else if (leftDist > rightDist && leftDist > obstacleThreshold)
  {
leftTurn();
}
else if (rightDist > leftDist && rightDist > obstacleThreshold)
  {
rightTurn();
}
else {stopTrolley();
}
delay (200);
}
else {stop Trolley ();
Serial.println("RF Tag not detected"); delay (500);
}
}
```

X. RESULT AND DISCUSSION

The Companion Cart: The Follower Trolley successfully demonstrates the use of embedded systems and wireless communication to develop an intelligent, user-friendly shopping assistance system. The proposed model was designed to reduce the physical effort of conventional shopping by enabling autonomous trolley movement via RF signal tracking. The integration of an Arduino Nano microcontroller, RF transmitter–receiver modules, relay driver circuits, and DC motors provides an efficient, low-cost solution for automated human-following.

The experimental analysis confirms that the system can reliably follow a user within an indoor environment while maintaining stable operation and responsive movement. The simplified hardware architecture without ultrasonic sensors reduces complexity, minimises power consumption, and improves affordability, making the system practical for real-world retail applications. In addition, the project highlights the growing importance of automation and smart technologies in enhancing customer convenience and improving the overall shopping experience.

XI. CONCLUSION

The study also reveals the potential of RF-based tracking systems in assistive and retail automation applications. The proposed trolley can be further enhanced by incorporating advanced technologies such as obstacle detection, RFID-based smart billing, IoT connectivity, mobile application integration, and AI-based navigation for improved accuracy and functionality. Overall, the Companion Cart represents a significant step toward developing intelligent retail infrastructure and future smart shopping ecosystems.

DECLARATION STATEMENT

After aggregating input from all authors, I must verify the accuracy of the following information as the article's author.

- **Conflicts of Interest/ Competing Interests:** Based on my understanding, this article has no conflicts of interest.
- **Funding Support:** This article has not been funded by any organizations or agencies. This independence ensures that the research is conducted objectively and free from external influence.
- **Ethical Approval and Consent to Participate:** The content of this article does not necessitate ethical approval or consent to participate with supporting documentation.
- **Data Access Statement and Material Availability:** The adequate resources of this article are publicly accessible.
- **Author's Contributions:** The authorship of this article is contributed equally to all participating individuals.

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