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Research Article

RFID-Integrated Prototype for Enhanced Shopping Experience for the Elderly

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ABSTRACT

A prototype that attempts to enhance senior citizens' weekly shopping experiences has been created as a result of this research. Seniors no longer have to use their physical strength to push or pull the shopping cart because the system monitors their every move. This is accomplished by estimating the user's walking direction and distance using a variety of sensors, such as a magnetometer and gyroscope. Furthermore, WiFi fingerprinting is used to pinpoint the user's location. Experiments have been carried out, and the system's overall functionality and tracking accuracy have produced satisfactory results. The smart shopping trolley concept has been designed to improve senior citizens' experience by addressing the unique challenges they face during the regular and necessary process of grocery shopping. The goal has been to increase senior citizens' comfort and convenience when shopping by integrating sensor-based solutions and tracking technologies. The successful results of the trials have confirmed the viability and efficacy of this strategy for sustainable practices in public health.

1. Introduction

Shopping can be particularly challenging for senior citizens, especially when it involves buying groceries. Many elderly individuals prefer to shop for themselves, even though options like helpers and online shopping are available, and they rely on assistance for carrying their bags home. The rise of the Internet of Things (IoT) and its extensive use in wireless communication is a direct result of the growing interest in integrating different systems, driven by technological advancements. In a variety of electronic gadgets and technologies, including smartphones, smart cars, smartwatches, and even smart homes, the word "smart" has grown in popularity. In keeping with this development, the ideas of "smart trolleys" and "smart shopping" have surfaced to offer seniors useful assistance. Smart trolleys with RFID technology make it simple to scan items as they are added to the trolley. The gathered data can be sent to the counter via ZIGBEE communication, cutting down on the amount of time people must wait in lines. Additionally, the use of RFID technology in smart trolleys can increase security by facilitating cashless transactions.

Recent research has focused on enhancing shopping experiences through RFID-integrated systems, particularly for elderly individuals. These systems aim to improve efficiency, reduce physical strain, and provide contactless purchasing options [1]. One prototype tracks elderly shoppers' movements using sensors and WiFi fingerprinting, eliminating the need to push or pull shopping trolleys [2], [3]. Another system, KONARK, utilizes RFID-equipped carts to enable faster checkouts and real-time purchase tracking, while also providing valuable data on customer interests to store owners [4]. The integration of RFID and sensor networks has shown promise in developing in-home elder healthcare systems,

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addressing the needs of an aging global population [5]. These technologies offer potential solutions for improving accessibility, reducing direct contact during pandemics, and enhancing overall shopping experiences for elderly consumers [1], [2], [6].

Furthermore, IoT standards must be implemented in order for purchased items, payment systems, and data collection to all work together successfully. This guarantees seamless connectivity and interoperability between the different elements that make up the purchasing process. The wireless telecommunications industry is witnessing a sharp increase in the Internet of Things (IoT) domain [7], [8]. Its goal is to free computers from direct human intervention so they can communicate with their environment and obtain information about objects and devices [9]. According to a report [10], Moderate data transmission speeds, low cost, and frequency range operation between 100MHz and 5.8GHz define Internet of Things. This development in wireless technology provides consumers with an adaptable and affordable communication option. A recent report [11], [12]. O'Neill in [13] predicted that by the year 2020, There will be 50 billion or more internet-connected devices, which will lead to an abundance of features. Research into the creation of smart shopping concepts has increased as a result of the growing need for convenient shopping experiences and the rising demand for technology. Fundamental functionalities such as tracking the user, navigating shopping routes, and preventing collisions with obstacles are integrated into these carts. With the use of this technology, elderly people should no longer have to deal with the physical strain and challenges that come with shopping, making the experience more comfortable and joyful. One of the main goals in the development of smart shopping trolleys has been the advancement of autonomous navigation. Scholars have been investigating diverse methodologies to facilitate self-navigating smart shopping trolleys. An automated smart cart system for contemporary shopping malls, for instance, was showcased, along with methods controlled by Android applications [7]. Thanks to developments in autonomous navigation, elderly people can now navigate the store without using their hands because the trolleys can now move on their own. The use of intelligent shopping carts in senior care offers a number of significant improvements and advantages. Other recent reports in [14], [15] describe a microcontroller-based smart trolley system for mega malls. Instead of having to wait in line to check out, customers can use a barcode scanner to automatically scan products and view running totals on an LCD display. The significance of RFID-based trolleys is underscored by a comprehensive analysis of 136 published papers in Scopus, highlighting the pivotal role these technologies play in enhancing efficiency and functionality within various industries. These studies collectively emphasize the transformative impact of RFID technology on inventory management, supply chain logistics, and customer service. The integration of RFID systems in trolleys has shown substantial improvements in tracking, monitoring, and managing goods, leading to streamlined operations and reduced errors. This not only bolsters productivity but also contributes to sustainable practices by minimizing waste and optimizing resource allocation. In alignment with the United Nations Sustainable Development Goals (SDGs), particularly SDG 12 (Responsible Consumption and Production), the adoption of RFID-based trolleys promotes resource efficiency, transparency in supply chains, and sustainable consumption patterns. By utilizing RFID technology in trolleys, organizations can enhance operational efficiency while advancing sustainable practices that align with global objectives for responsible consumption and production. Fig.1 illustrates the distribution of these publications in the last two decades.

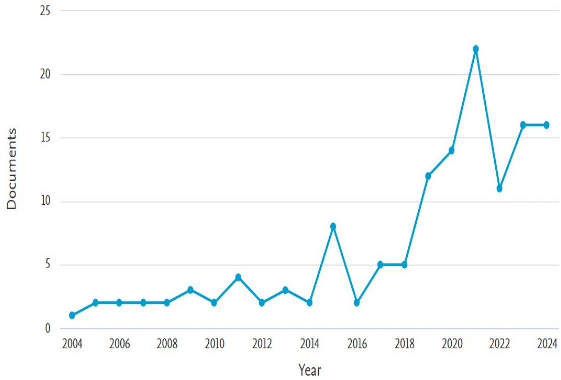

Fig.1 Scopus indexed publications since 2004. (scopus generated graph)

As depicted in Fig.1, from 2004 to 2014, there is a gradual increase in the number of publications. This suggests a growing interest and research in RFID-based smart trolleys during this period. Between 2014 and 2020, there is a more pronounced upward trend, indicating a significant boost in research and development activities. The peak in 2020 suggests heightened activity or breakthroughs in this field. After reaching a peak in 2020, there is a sharp decline in 2021. This could be due to various factors such as market saturation, shifts in research focus, or external factors like economic downturns. However, there is a recovery noted in 2022, followed by a slight drop in 2023 but stabilizing in 2024. The overall trend from 2004 to 2024 shows an increasing trajectory, indicating that RFID-based smart trolleys have gained considerable attention over the years and continue to be a relevant topic of research. The publications in [16], [17], [18] indicates that the use of smart trolley is an area that is continuously evolving, with interest levels fluctuating but generally on an upward trend. This reflects the growing recognition of the potential applications and importance of this technology in enhancing the shopping experience through technological innovations. The analysis suggests that the interest in RFID-enabled smart trolleys is dynamic, with periods of highs and lows, but an overall increasing trajectory. This points to the growing awareness of the value this technology can bring in improving the shopping experience for consumers, as technological advancements continue to shape and refine the capabilities of these smart systems. The analysis highlights that the field of RFID integration in smart trolleys is one that is continuously being explored and developed, with researchers and industry players recognizing the significant impact it can have on enhancing the shopping journey for customers. The fluctuating, but generally rising, interest levels indicate that this technology is gaining traction and momentum as a means to leverage technological innovations to create more seamless and convenient shopping experiences.

This paper presents an innovative smart shopping trolley design. The key feature of the proposed smart trolley is that it eliminates the need for users to physically push or pull the cart. Instead, the smart trolley is designed to autonomously follow the user, making the shopping experience much easier and more convenient. Researchers have developed a novel smart shopping cart that addresses a common pain point - the effort required to maneuver a traditional shopping trolley. By designing the trolley to automatically follow the user, the team has sought to alleviate the burden on shoppers, particularly the elderly or those with physical limitations. At the heart of this smart trolley is the capability to track the user's movements and trajectory, and automatically adjust the trolley's position and direction accordingly. This innovative approach aims to enhance the overall shopping journey, freeing up the user's hands and energy to focus on their shopping tasks rather than the physical exertion of pushing a cart. The introduction of this smart shopping trolley concept represents a meaningful step forward in improving the shopping experience through the integration of advanced technologies. By designing a trolley that can independently follow the user, the researchers have sought to create a more seamless and effortless shopping experience for consumers.

2. Methodology

The process of developing an RFID-based smart shopping trolley can be broken down into three main phases: hardware interface, design process, and fabrication and testing. In the initial hardware interface phase, the researchers begin by carefully selecting an appropriate microcontroller, such as an Arduino or Raspberry Pi, based on factors like processing power, input/output capabilities, and compatibility with RFID modules. Next, they integrate DC motors, choosing them based on the required torque and speed for the trolley, and design a suitable mounting system. An H-Bridge dual motor driver is then chosen and integrated to control the direction and speed of the DC motors. The circuit schematic is designed to connect the microcontroller, motors, and H-Bridge, with the implementation of PWM for speed control. Finally, the RFID module is integrated, ensuring proper communication with the microcontroller. The design process phase starts with a thorough requirement analysis, where the team defines the functional and non-functional requirements for the smart trolley. They then move on to system architecture design, creating a high-level blueprint of the smart trolley system, including both hardware and software components. The software design follows, where algorithms are developed for motor control, RFID tag reading, and overall system logic. User interface design is the next step, where the researchers create an intuitive interface for users to interact with the trolley. Finally, a design review is conducted to ensure all components are properly integrated and the design meets the initial requirements. The fabrication and testing phase begins with the construction of a physical prototype, where the team builds the trolley structure and integrates all the hardware components. They then assemble the hardware, meticulously ensuring proper wiring and connections. A comprehensive testing plan is developed to evaluate the functionality of the smart trolley. The researchers conduct initial tests to verify motor control, RFID reading, and overall system integration, followed by user testing in real-world scenarios. The final step involves analyzing the test results, identifying areas for improvement, implementing necessary modifications, and re-testing the system to ensure all issues are resolved.

2.1. Micro Controller Unit (NodeMCU)

In this project, the main controller used is the NodeMCU micro-controller with the integrated WiFi module. An open-source Lua-based firmware called NodeMCU is used for the ESP8266 WiFi SoC from Espressif, and it features an on-module flash-based SPIFFS file system. C programming language is used for the implementation of the NodeMCU, simplifying its use in IoT projects. The key reason for the selection of the NodeMCU is its integrated WiFi module, which allows for seamless connectivity and integration with the broader Internet of Things (IoT) ecosystem [19], [20]. The open-source platform of the NodeMCU, which runs on the Lua programming language, has been based on the ESP8266 WiFi system-on-a-chip (SoC) from Espressif, a leading manufacturer of IoT-focused microcontrollers. The SPIFFS (Smart Persistent File System) has been utilized for on-module flash-based file storage on the NodeMCU. The decision to use the NodeMCU in this project reflects the desire to leverage an IoT-centric microcontroller that offers built-in WiFi capabilities, allowing for seamless integration with various IoT applications and services. Furthermore, the C programming language implementation of the NodeMCU has been found to be a user-friendly and accessible option for developing IoT-based projects, enabling the researchers to more efficiently architect and implement the control systems for the smart trolley.

2.2. DC motor

A DC motor in use would have just two terminals. These terminals lack polarity because their only means of connection is a coil. Only the motor's direction will change if the connection is reversed.

2.3. *Inertial gyro sensor*

To help us monitor rotation, we have incorporated a gyroscope—a specialized sensor—into our suggested design. The accelerometer that is integrated into this sensor is pretty smart; it measures the speed at which an object moves in a straight line. Thus, the gyroscope provides information on the angular rotation of the user, whereas the accelerometer provides information on the user's linear movement. We can precisely detect and comprehend the user's movement by merging these two sets of data. This sensor is ideal for our project because it is affordable and small, which is another fantastic feature. We wanted to make sure that the parts we selected are both reasonably priced and functional.

2.4. *H-Bridge dual motor controller L298N*

The motor's current flow must be reversed in order to control the direction in which the motor rotates. The most popular way to accomplish that is with an H-Bridge circuit. Four switching components, either transistors or MOSFETs, make up an H-Bridge circuit. The motor is positioned in the middle, creating an H-shaped arrangement. The direction of the current flow and, consequently, the direction in which the motor rotates can be altered by simultaneously activating two switches. The L298N is utilized in this project as a dual H-Bridge motor driver, enabling simultaneous control of two DC motors' speeds and directions.

3. Design and fabrication

In the world of shopping trolleys, various types have been introduced over the years. However, a more advanced solution has been developed through this project - a smart shopping trolley that aims to bring unprecedented convenience to the shopping experience. The key innovation lies in the integration of Wi-Fi technology, which allows users to control the shopping trolley using their smartphone. Through a real-time Wi-Fi connection established between the trolley's micro-controller and the user's smartphone, seamless guidance and navigation of the trolley have been made possible. All the user needs to do is install a dedicated app on their smartphone and use it to send commands to the micro-controller via the Wi-Fi signal. This effortless interaction between the user and the trolley is akin to having a personal assistant catering to one's shopping needs. Imagine the ease of simply tapping a few buttons on your phone to direct the trolley to your desired destination within the store. This level of control and convenience has been made a reality through the technological advancements incorporated into this smart shopping trolley project. The seamless integration of Wi-Fi connectivity and the smartphone-based control interface have transformed the traditional shopping trolley into a more intelligent and user-friendly companion, enhancing the overall shopping experience for the end-user. Yet, we didn't just prioritize convenience. Ensuring the safety of both the user and the trolley was also a priority for us. In order to enhance the safety features of the smart shopping trolley, an ultrasonic sensor has been integrated right at the front of the device. This sensor is essential in preventing mishaps and potential damage from abrupt stops or collisions. The ultrasonic sensor detects sound waves by bouncing them off objects and then listening for the echoes that return. The sensor measures the distance between the trolley and any obstacles in its path precisely by analyzing the time it takes for the sound waves to travel and return. This enables the trolley to use the signals it sends and receives to modify its movement and prevent any collisions. The smart shopping trolley now combines the ease of smartphone-controlled Wi-Fi technology with the extra security and safety features thanks to the integration of the ultrasonic sensor. The sensor's ability to detect and respond to obstacles in the trolley's path ensures a secure and seamless shopping experience for the user. With this added layer of safety, the smart shopping trolley aims to provide users with a reliable and confident shopping companion. The integration of the ultrasonic sensor, alongside the smartphone-controlled Wi-Fi functionality, has transformed the traditional shopping trolley into a more intelligent and user-friendly solution, effortlessly guiding the user through the store while avoiding obstacles along the way. In essence, this smart shopping trolley project has been designed to enhance the overall shopping experience by offering both convenience and safety, giving users a sense of control and peace of mind throughout their shopping journey. The operation of ultrasonic sensor has been shown in Fig. 2.

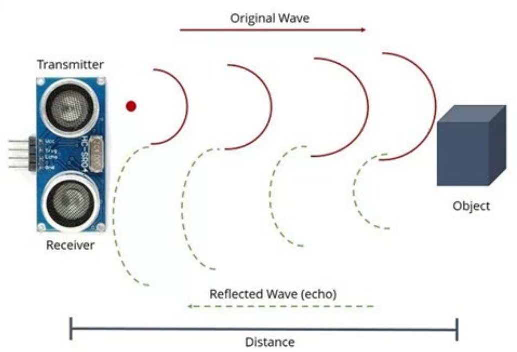

Fig.2 Obstacle detection via ultrasonic sensor

Fig. 2 depicts the working principle of an ultrasonic sensor used for obstacle detection. The key components of this system are the transmitter and the receiver. The transmitter, a small rectangular device with a red dot, is responsible for emitting ultrasonic waves, represented by the curved lines radiating outward. As these waves encounter an obstacle, such as an object or another entity, they bounce back, creating a reflected wave or echo, which is then detected by the receiver - another small rectangular device similar to the transmitter. The reflected waves, shown as dotted lines returning to the sensor, symbolize the ultrasonic waves bouncing off the object and reaching the receiver. By measuring the time it takes for the waves to travel and return, the sensor can accurately determine the distance between the device and the obstacle, as indicated by the markings on the horizontal line. This seamless integration of sound wave transmission, reflection, and distance calculation allows the ultrasonic sensor to detect and respond to any obstacles in its path, enabling the system to adapt and navigate accordingly.

In order to properly integrate the ultrasonic sensor into the shopping trolley, the necessary electrical connections must be established. This involves connecting the power supply (VCC) and ground (GND) pins of the sensor to a 5V power source, ensuring the sensor receives the required power. Additionally, the trigger input (Trig) pin is linked to a digital output on the trolley's microcontroller, which is responsible for initiating the ultrasonic wave transmission. Correspondingly, the echo (Echo) pin is connected to a digital input on the microcontroller, allowing it to detect and process the reflected ultrasonic waves. This integration of the sensor's power, trigger, and echo connections with the trolley's microcontroller enables the seamless operation of the obstacle detection system, allowing the trolley to adapt its movement and ensure a safe shopping experience for the user.

A particular method is used to calculate the exact distance between the shopping trolley and any obstacles that are detected. This entails briefly pulsing the ultrasonic sensor's trigger pin to a high level, usually for ten microseconds. The system then waits for a high-level signal to be detected on the echo pin following this trigger pulse. The time it takes for ultrasonic sound waves to move from the sensor to the obstruction and back again is represented by the duration of this high-level echo signal. The system can precisely calculate how close the trolley is to the identified obstacle by examining this response time and the length of the echo signal. The trolley's ability to measure distance enables it to detect and steer clear of obstacles, providing users with a seamless and safe shopping experience. Here's how to calculate the distance:

$$D = T \times \vartheta = T \times 0.034 cm/\mu s \qquad (1)$$

Where D is a distance , T is a time and ϑ is the speed of sound.

The prototype layout is illustrated in Fig. 3. As depicted in this diagram, the microcontroller unit, two motors, motor controller, and ultrasonic sensor, are interconnected as the primary elements of our suggested configuration.

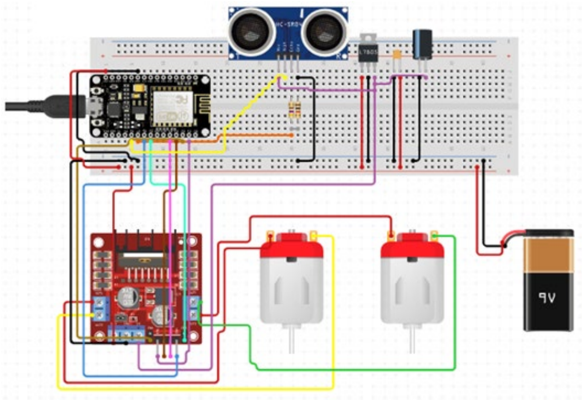

Fig.3 Schematic creation for the envisioned trolley

The Node MCU, which is well-known for its 16-bit RSIC and energy efficiency, is used as a controller because of its convenient WiFi module and integrated ESP-12, which simplify the control procedure. The CPU clock speed of the ESP-12 is 80MHz, with a maximum value of 160MHz possible. The DC motors are connected to the microcontroller via the L298N motor controller. A 9V battery is used in parallel to power the microcontroller and the L298N motor controller. The movements of the trolley are defined by the programming of the controller, as shown in Table 1.

Table1: Motor control instruction

Motor Movement	Right moto	Left motor
Turn right	NA	High
Turn Left	High	NA
Forward	Low	High
Backward	High	Low

The control commands are transmitted to the microcontroller via the application developed using the MIT App Inventor. The block functionality of the designed application is illustrated in Fig. 4. The underlying working principles of an ultrasonic sensor deployed for the purpose of obstacle detection are herein expounded upon. A detailed dissection of the system's constituent elements is warranted to elucidate the sensor's modus operandi. The component responsible for emitting the ultrasonic waves is identified as the transmitter, depicted as a compact, rectangular device with a prominent red dot, ostensibly denoting the point of sound emission. These outward-traveling waves, represented by the curved lines emanating from the transmitter, constitute the original sound impulses. When these waves encounter an object, or obstacle, in their path - in this case, a dark gray cubic form - they are reflected, generating the echoed waves illustrated by the dotted lines returning to the sensor. The receiver, a complementary compact rectangular component akin to the transmitter, is tasked with the detection of these reflected waves.

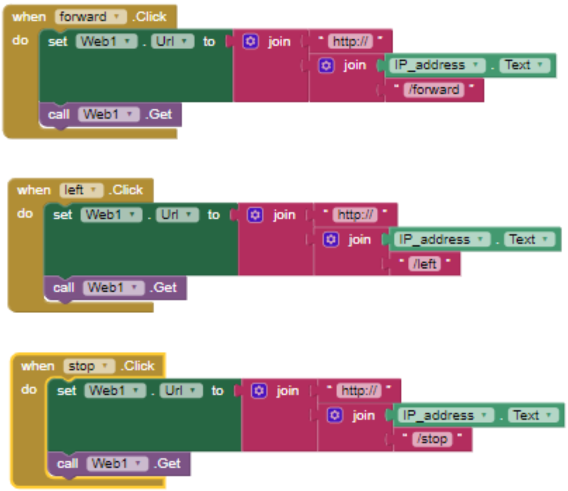

Fig.4 The controlling function block of the app

The construction of the suggested prototype is depicted in Fig. 5.

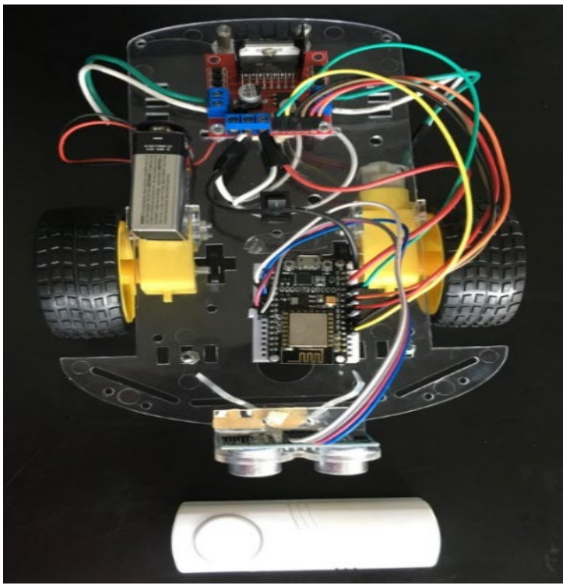

Fig.5 The constructed model

4. Conclusion and Future Work

A smart shopping cart specifically designed for senior care has been successfully designed, manufactured, and tested. The outcomes have been extremely satisfying, proving that the suggested solution is effective. With the use of cutting-edge technology, the smart trolley can identify the gait patterns of senior citizens and follow them on its own. This eliminates the need for users to push or pull the trolley physically, making shopping more comfortable and convenient. It has been determined that there is room for future development and expansion of the smart shopping trolley. The incorporation of GPS technology is one potential area of future investigation. Instead of being restricted to indoor use, the GPS-enabled trolley can precisely determine its location both indoors and outdoors, simplifying user navigation and facilitating the trolley's return to its initial position. With this improvement, users would have even more flexibility and convenience, which would improve the effectiveness and enjoyment of their shopping trips. To sum up, the intelligent shopping cart designed for senior care has demonstrated encouraging outcomes, providing a convenient and support-oriented method of shopping. Future versions of the trolley could benefit from the addition of GPS technology, which would increase its adaptability and functionality and give senior shoppers a more comfortable and seamless shopping experience

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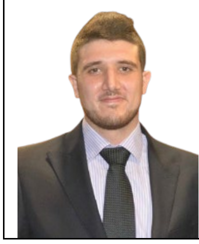

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