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Design and Development of Autonomous Shopping Trolley with Automatic Billing System

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ABSTRACT

In supermarkets and shopping malls, it is often difficult to find the item that one is looking for, among the various rows and shelves. In such a scenario, an automated trolley can guide the user to reach the exact location of the item, thereby making his shopping experience more comfortable. With additional features like an automatic billing system, long queues and periods of waiting can also be avoided. The primary objective of this project is to design and develop a smart and autonomous shopping trolley that is capable of moving towards selected items and automatically computing the bill. To achieve this, we have employed a line follower robot with obstacle avoidance to control the trolley's movement. The trolley is controlled using an LCD and keypad interface that utilizes the Arduino platform, allowing customers to select the desired items. Various sensors and actuators, including infrared and ultrasonic sensors, and motors are integrated into the system to detect and navigate around obstacles and guide the trolley towards the selected items. Furthermore, the project includes a billing system that computes the total cost of the selected items and displays it on the LCD screen. Overall, this project offers a cost-effective and convenient solution for customers to carry out their shopping efficiently without any manual intervention.

I. INTRODUCTION

The use of autonomous systems is spreading across several industries, including logistics and transportation. The creation of intelligent, autonomous trolleys that can handle a variety of activities, including distribution, inventory management, and transportation, is one of the most exciting uses of autonomous technology. One of the most promising applications of autonomous technology is the development of smart autonomous trolleys, which can perform various tasks such as transportation, delivery, and inventory management. These trolleys are equipped with sensors and cameras enabling them to operate autonomously, without the need for human intervention. The use of smart autonomous trolleys offers significant advantages such as increased efficiency, reduced labor costs, and improved safety. The usage of autonomous systems is spreading across several industries, including logistics and transportation. These trolleys can move around the store, identify and avoid obstacles, communicate with consumers, and also generate automatic billing for the items selected and deselected accordingly. The Usage of intelligent autonomous trolleys can decrease the demand for human labor, lower the risk of accidents and theft, and improve the accuracy of inventory management.

This paper introduces and explores the development and potential applications of smart autonomous Shopping Trolleys to assist people in supermarkets and grocery stores as well as the challenges and limitations that need to be addressed for their successful implementation. Such a robotic system must be capable of automatically carrying customer's groceries as they shop. Most people today do not want to spend more time walking down every aisle looking for the items on their lists, especially if the customer does not know where the items are kept. And therefore, we suggest a line-following robotic system that can operate autonomously based on the products customers choose and that can generate automatic billing for the chosen products. In that, the products selected and the total generated amount which is automatically calculated for the selected products will display on the LCD screen. So that the customer's would not have to wait in a long queue at the checkout. Here the billing system is done based on transferring the data from the interfaced 4×4 keypad matrix which already stores the product names and the amount of each product. Also, the customer can add or remove the product based on their requirement.

Our smart trolley will be able to move along the black taped-out path. For the purpose of detecting the black tape- created line or path on any coloured surface, infrared sensors are used. In order to prevent the robot from straying from the track or the path marked out with black tape, the Analog signal received from the infrared sensors will be analyzed. In addition, we use the camera as a source for obstacle avoidance and detection and for adjusting the path accordingly. So that the customer's shopping experience will be more enjoyable and successful with the help of a smart autonomous trolley.

The following is the paper's contribution: We reviewed a variety of currently used techniques for autonomous smart trolleys for supermarkets, as well as their implementations, outcomes, and discussions based on feedback from customers.

II. RELATED WORKS

S. Shailesh et al. (2021) proposed a solution to long queues at billing counters in supermarkets by implementing a barcode-based system with an LCD display on the trolley using a Raspberry Pi. The authors included two buttons on the trolley to allow the addition and subtraction of items from the automated billing system on the trolley. Shankar et al. (2021) proposed a time-efficient billing system based on IoT. This requires the product to have a barcode, and the trolley to have a barcode reader, an LCD display, and a Raspberry Pi. In order to enhance the customer experience in the supermarket, a QR code for the payment is additionally generated so that the customer can directly pay using any UPI payment application. Thus, the overall waiting time is predicted to be reduced by half of what was initially present.

D. D. Pradhan et al. (2021) proposed a time-efficient billing system where the customers can directly pay their bills by logging into an online portal. Such a system allows multiple customers to process their shopping and pay their bills simultaneously rather than wasting time by waiting in long queues at the checkout.

T.R. Lekhaa et al. (2019) suggested an IoT method to reduce the time spent at a supermarket by the use of the Bolt ESP8266 or Wi-Fi module, which along with the barcode-based system with LCD, which leads to reducing not only the time spent in a supermarket but also the number of salespersons required. The ease of use of the Bolt ESP8266 is an added advantage. P. A. Jeyanthy et al. (2022) used an Arduino-based system with the help of

RFID tags to design and develop a smart shopping trolley. Such a system can reduce the time spent for billing while shopping with the help of the Zigbee module and concepts of IoT as billing is done automatically when the item is placed in the trolley. Moreover, this design includes both online and offline payment options.
A. A. Santoso Gunawan et al. (2021) developed a smart trolley system based on the line-following algorithm in which the Arduino served as the microcontroller and the localization was performed by using RFID. The authors made use of Mecanum wheels which provide an omni-directional movement without having to move the wheels. The conversion from a normal trolley to the developed trolley system is quite easy as the robot has to be simply placed over the trolley. An additional feature is the android application, that is connected to the trolley over Bluetooth, helps in locating the item that the customer is looking for. T. Hanooja et al. (2020) developed an automated customer following shopping trolley which works based on color tagging by using a Raspberry Pi and a camera. Such a system can easily be implemented on the regular trolley, hence making the transition from the normal shopping trolley to the smart shopping trolley, much easier. This method was also aimed to aid the elderly and the children - who might possibly find it difficult to move the trolley around, but the major drawback was the non-user-friendliness of the system. The authors proposed that each trolley would have a corresponding color tag which the customers would have to carry around so that the trolley could follow. M. Rajagopalaswamy et al. (2022) presented a trolley prototype that makes use of an accelerometer, ADXL-335 to sense the hand gestures and pass on the corresponding signals to the receiver via a wireless RF transmitter. An L293D driver drives the motors in the receiver to cause the trolley to move based on the signals received by the receiver. Therefore, the trolley moves based on the hand gestures of the customer.

III. PROPOSED METHODOLOGY

This study focuses on the development of an intelligent and self-guided shopping cart that can assist customers in locating the specific items they need, enhancing their overall shopping experience. The initial phase of our research involved designing an input device that allows customers to select their desired items. To accomplish this, we utilized a 4x4 Keypad Matrix, which enables the selection of up to 16 distinct items. Initially, we started with a selection of eight items arranged in two rows of four, and in the later stages of our project, we added a greater number of items, arranged in different rows. These items can be conveniently chosen by pressing the corresponding buttons on the keypad, numbered from 1 to 8. To facilitate the purchasing process and provide customers with a clear understanding of item prices, we assigned each item a specific price. A comprehensive table outlining the individual items and their corresponding prices is shown in Table1.

TABLE 1. List and price of items selected and designed under phase 1 of our model.

Sl.no	Items	Price in rupees (₹)
1	Soap	30
2	Sugar	40
3	Biscuits	10
4	Cake	100
5	Juice	60
6	Chips	30
7	Toys	80
8	Shoes	1000

The selection of required items is achieved by pressing the corresponding number button on the keypad, with the selected numbers being simultaneously displayed on the LCD screen. However, if a customer mistakenly selects the wrong number or decides to remove a previously chosen item from their cart, they can easily delete it using the * button on the keypad. This function deletes the previously selected item, with the changes being immediately reflected on the LCD screen. Customers can use this method to delete as many items as they want while continuing to add items from the keypad. Once all the desired items have been selected, the customer can press the # button, indicating that the selection process is complete, and no further changes will be made. At this point, all the selected items and their corresponding prices are displayed on the LCD screen, and the total cost of the chosen items is automatically calculated and shown on the screen.

The second phase of our research involves designing a trolley that can automatically navigate to the location of the selected item. To accomplish this goal, we have utilized a line following robot equipped with obstacle avoidance capabilities. The robot is equipped with infrared sensors (IR) that enable it to follow a black line on the floor.

Additionally, it is equipped with an ultrasonic sensor that detects obstacles in the trolley's path and enables it to navigate around them. Each item within the supermarket has a corresponding barcode attached to it. As the line following the robot moves along the black line on the floor, the attached scanner reads the barcode of each item encountered. If the barcode matches an item selected by the user, the robot stops momentarily, indicating that it has reached the item's location. The selected item is displayed on the LCD screen, alerting the sales workers to place the item inside the trolley. Once the item is placed, the trolley resumes its movement. This process is repeated for all the rows of the shopping mall until all the items required by the user are collected within the trolley.

System Architecture

FIGURE 1. The overall design of our model is represented in the block diagram

Hardware Architecture

In order to optimize the cost-effectiveness of the smart trolley, we have developed an Arduino-based line-following robot equipped with obstacle avoidance capabilities to control the trolley's movements. The primary components utilized in the creation of this robot are as follows: An Arduino Uno development board, which serves as the central controller for interfacing with all other components and programming them accordingly. An infrared sensor (IR), which detects the black line on the floor and enables the robot to adjust its movements to remain on the line. An ultrasonic sensor, which detects obstacles in the trolley's path and allows it to navigate around them. A 200 RPM gear motor, which drives the robotic wheels, and an L298N motor driver, which controls the motion and movement of the gear motors. A 18650 rechargeable lithium-ion battery (12V) provides the power to operate the motors, and a metal chassis serves as the skeleton to hold all the components, resembling a robotic car.

To develop an input and output device for this project, we have utilized a 4x4 keypad matrix to select the number of items and an LCD display to show the selected items and their total cost.

The table below provides detailed information on the hardware components, including their specifications and how they benefit our project.

TABLE 2. List of Components and their Specifications

Sl.no	Components	Cost
1	Arduino Uno	₹ 500
2	4x4 Matrix Keypad	₹65
3	200 RPM Gear Motor	4 x ₹130
4	L298N Driver	2 x ₹125
5	18650 Li-ion battery	3 x ₹70 + ₹170
6	Metal Chassis	₹100
7	Wheels	4 x ₹45
8	Ultrasonic sensor	3 x ₹70
9	IR Sensor	₹30
10	LCD	₹120
11	OV7670 Camera	₹160

Circuit Diagram

Fig 2.a. illustrates the connections of various sensors and motors to the Arduino board to construct a line follower robot. Our design employs two infrared (IR) sensors and one ultrasonic sensor to capture the input from the surrounding environment. These sensors are linked to the Analog pins of the Arduino board. Based on the input obtained from the sensors, the Arduino board issues commands to the L298N Motor Driver to regulate the motion of the wheels connected to the 200 RPM Gear motors. The command instructs the robot to turn left or right, move forward or backward based on the sensor input. The Arduino is provided with an input voltage of 5V to operate the program and issue commands.

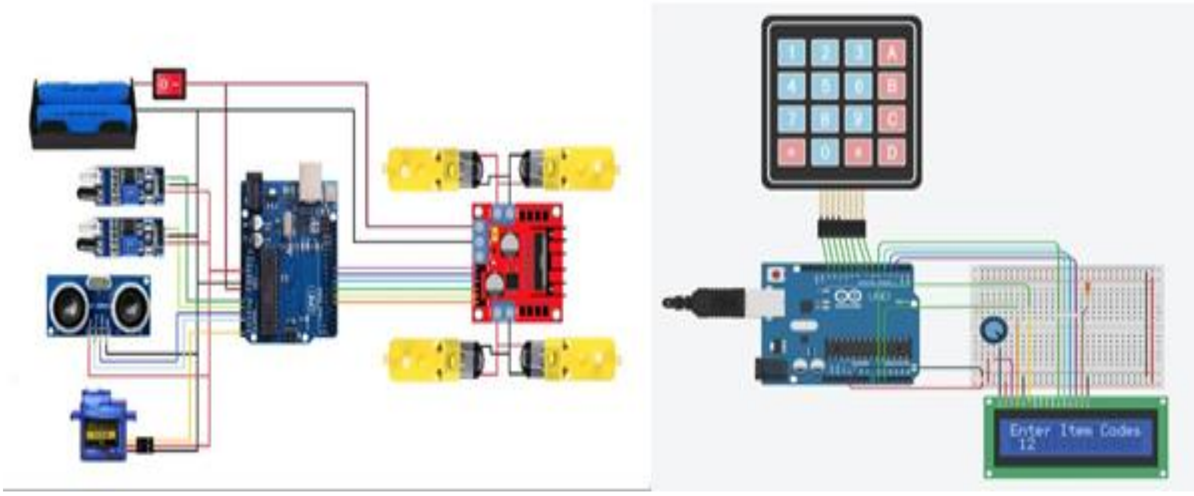


FIGURE 2. (a) Line following Robot with obstacle avoidance mechanism (b) Integration of a 4x4 keypad matrix and an LCD display with the Arduino board to create an input and output device for our project.

Software Architecture

The software for this project was developed using the Arduino platform and programmed in the C++ language. The programming is structured such that the trolley follows the black line marked on the floor using two IR sensors, and the obstacle avoidance mechanism is accomplished through the use of an ultrasonic sensor. The algorithm for the line following robot is implemented in a step-by-step manner to ensure the seamless operation of the trolley.

Algorithm:

If (Right_IR_Sensor==0 and Left_IR_Sensor==0) : Go_forword();

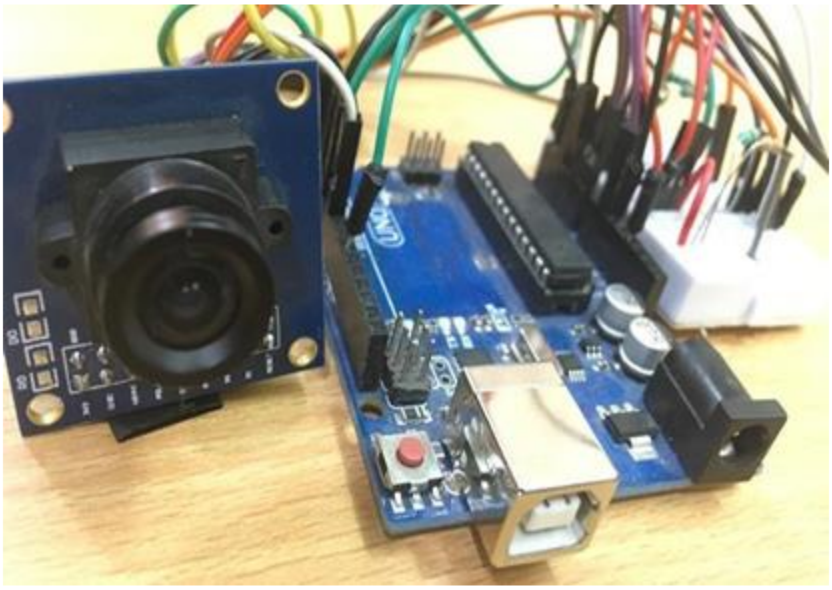
Else If (Right_IR_Sensor==0 and Left_IR_Sensor==1) : Turn_left();

Else If (Right_IR_Sensor==1 and Left_IR_Sensor==0) : Turn_right();

IV. RESULTS AND DISCUSSION

Shopping malls and supermarkets are the places where consumers buy their daily necessities for their day-to-day lives. With consumers taking advantage of ease, variety, and the ability to evaluate costs, online purchasing usage is continuing to rise year over year. Therefore, it is an uphill task for supermarkets and shopping malls to draw consumers into their establishments and compete with the benefits of online purchasing. To achieve this, they must provide the best possible in-store customer experience, with the customers' desires and needs always taken into account and provided for.

Customers spent more time waiting at billing counters than shopping, according to analyses, thereby reducing overall store productivity. We came up with an idea to reduce the time consumers spend at the bill counters and increase productivity and profitability by installing a smart trolley system in the stores. The automated trolley is a self-driving cart that can move through a store setting without human assistance. The trolley was equipped with a range of sensors, which allowed it to detect and avoid obstacles. It is helpful for people to get their total bill once they enter items through the keypad. Another advantage is that elderly and physically challenged people don’t have to move around the store to find the products that they want to buy. The system's implementation costs less than most other products that utilize the Raspberry Pi to function. Once it is successfully implemented, it will be of great benefit to both consumers and shop owners.



(a)

(b)

FIGURE 3. OV7670 Camera Module and its output

Implementation

The prototype trolley is built with two infrared sensors that detect the black line on the floor and move along it. The IR sensor is placed in such a way that it can detect the black line and take a turn if an obstacle arises. It will then move according to the predetermined path the black line follows.If the model goes outside the black line, it readjusts itself to follow the line accordingly.

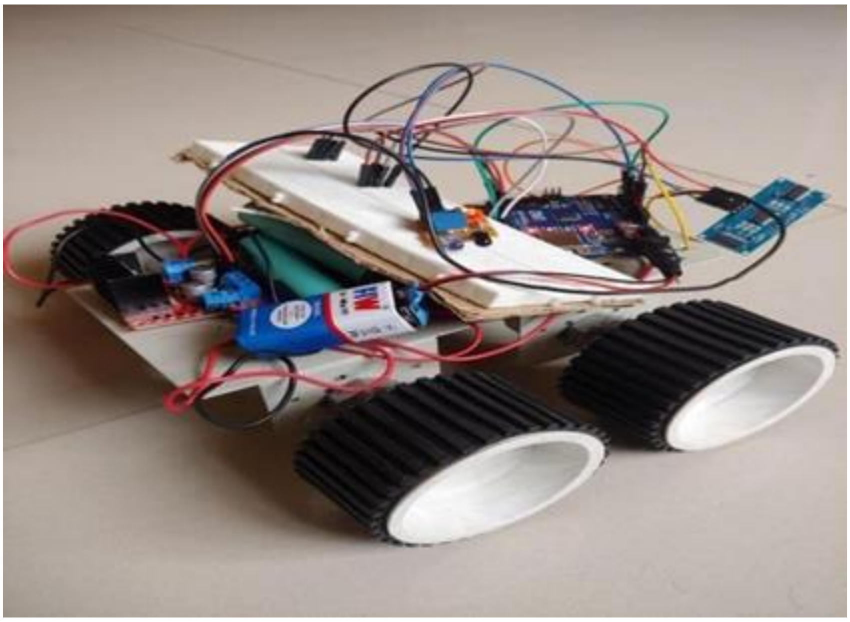


FIGURE 4. Basic prototype model of the trolley.

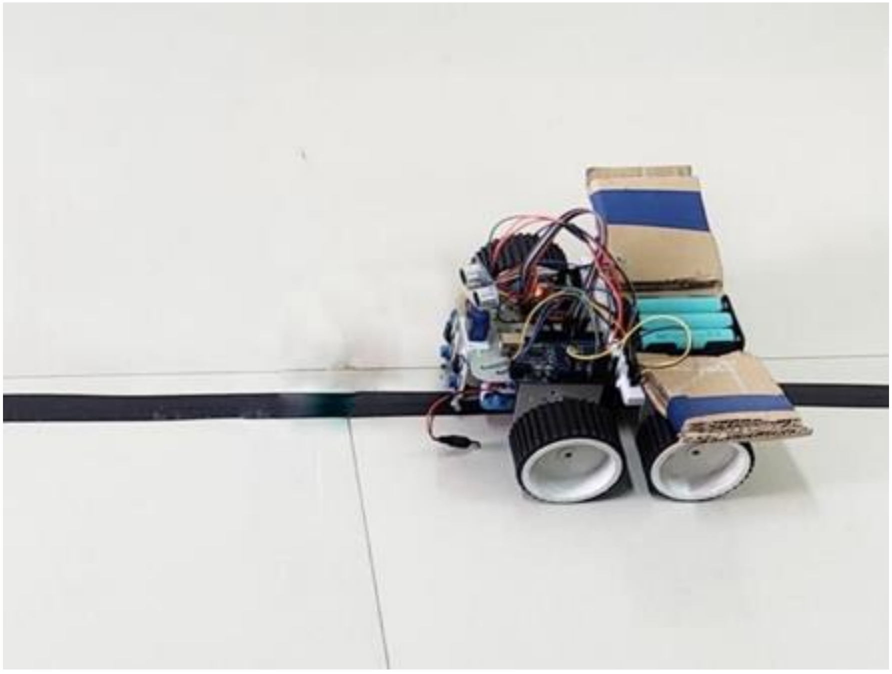


FIGURE 5. Fixed path that the prototype model follows.

In the initial stage of designing the model, we declared ten items in the Arduino code. The LCD and keypad were integrated using Arduino coding to allow customers to select their desired items by entering the item number. After entering the item number, the corresponding item name and price were displayed on the LCD screen. Figure 3 illustrates the LCD displaying the total amount to be paid after selecting all the desired items.

The study's findings imply that the smart shopping cart can completely transform how consumers purchase their products. Customers may be able to make more informed purchases by using the total bill the system provides at the starting stage after they input the products into the keypad. This may result in higher customer happiness.

The project's disadvantage is that security may be an issue, and the model must be trained in a crowded area to ensure that it operates without any hindrances. The price of implementing the technology is one possible issue, which could be problematic for smaller shops or those with limited resources. The requirement for teaching employees and customers how to use the technology successfully presents another potential challenge.
In conclusion, the smart shopping trolley is an innovative device with the ability to improve consumer purchasing experiences. The viability and cost-effectiveness of utilizing this technology on a larger scale require further study. The smart trolley has the potential to be a useful instrument for both consumers and retailers if it is applied properly.

V. CONCLUSION

The development of a smart and autonomous shopping trolley is a promising solution to address the challenges faced by customers in large supermarkets and shopping malls. The integration of advanced sensors, actuators, and a billing system in the trolley enhances the customer's shopping experience, making it more comfortable, efficient, and convenient. The use of the Arduino platform, line follower robot with obstacle avoidance, infrared, and ultrasonic sensors, and motors has enabled the trolley to navigate around obstacles and reach the desired items accurately. With this technology, customers can select items without any difficulty and avoid long queues and waiting times. This project offers a cost-effective solution to enhance the shopping experience, and it could have significant implications for the retail industry,

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