

AutoShelf: Autonomous Trolley with Robotic Arm for Item Replacement

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Abstract: This work is focusing on the development of a flexible and intelligent sensor- controlled trolley to support physical distribution of goods. Transporting goods is a common trend in laboratories, offices, supermarkets warehouses and industrial settings. In developing countries, handling and transporting of materials are usually done using manually operated trolleys. Such practice could be time consuming and laborious, thus this work will help to reduce the human effort. The Product/Goods Managing Trolley in Supermarket using Arduino with Robotic Hand is an automation project designed to simplify shopping and inventory handling in supermarkets. In this system, a smart trolley integrated with Arduino microcontroller and a robotic arm (robotic hand) helps customers pick and manage goods automatically. The robotic hand can pick items from shelves and place them in the trolley, while sensors detect the presence of products. The system reduces manual effort, improves shopping efficiency, and demonstrates automation in retail environments.

Keywords: Embedded system, Robotics, Automation, Sensors, Autosshelf, Autonomous Trolley

I. INTRODUCTION

The AutoShelf: Autonomous Trolley with Robotic Arm for Item Replacement is an innovative robotic system designed to automate the process of identifying, retrieving, and replacing items on shelves without human intervention. The system integrates a control board, autonomous navigation using line-following and obstacle detection sensors, and a robotic arm for precise pick-and-place operations. It is powered by a rechargeable battery and features communication modules such as RFID, barcode scanners etc and real-time data exchange. The trolley navigates along with predefined paths using line follower sensors accurately interacts with shelves to manage items. This automation enhances operational efficiency, reduces human effort, and ensures accuracy in restocking and item replacement in environments like warehouses, libraries, and supermarkets.

Automation and robotics are increasingly used in modern inventory management systems to reduce manual work and improve efficiency. Traditional restocking in supermarkets and warehouses requires human workers to manually check shelves and place items, which can be time-consuming and error-prone. The AutoShelf system introduces an autonomous trolley equipped with a robotic arm capable of item replacement and restocking. Using sensors and identification modules such as RFID or barcode readers, the trolley can identify items and their correct shelf positions. The robotic arm then performs pick-and-place operations to organize or restock products. This project demonstrates the integration of embedded systems, robotics, and sensor technology to create an automated shelf management system.

A. Problem Statement

In large-scale warehouses, supermarkets, and libraries, manual item replacement and restocking are time-consuming, labor-intensive, and prone to errors. Human workers often face challenges in identifying the correct shelf location, handling items accurately, and maintaining inventory consistency. These repetitive tasks not only reduce operational efficiency but also increase the risk of misplaced items and physical strain on workers.



Existing shelf management systems still rely heavily on manual intervention or semi-automated trolleys that lack precision and autonomy. There is a pressing need for an intelligent system that can navigate autonomously, identify shelves and items, and perform pick-and-place operations without human involvement.

Therefore, the problem addressed by this project is the lack of a fully autonomous and intelligent system capable of performing accurate item replacement and shelf management operations. The AutoShelf project aims to overcome these limitations by developing an autonomous trolley equipped with a robotic arm, integrated sensors, and item identification technology to ensure efficient, accurate, and safe item handling in structured environments.

B. Need and Necessity of Project

The need for this project arises from the growing demand for automation and efficiency in inventory management and item handling processes. In modern industries, warehouses, retail stores, and libraries, a significant amount of time and manpower is spent on routine tasks such as restocking shelves, organizing items, and replacing misplaced products. These repetitive operations not only slow down productivity but also increase human fatigue, operational costs, and the likelihood of human error.

As the scale of storage and retail systems grows, manual methods become inefficient and unsustainable. Hence, there is a strong requirement for a smart, autonomous system that can handle these tasks with minimal human supervision. The AutoShelf system addresses this need by combining autonomous navigation, robotic manipulation, and intelligent item identification to automate the process of shelf management.

- Reducing human effort and labor dependency in repetitive tasks.
- Improving accuracy in item placement and retrieval.
- Enhancing operational speed and inventory control.
- Ensuring safety by minimizing human interaction in potentially hazardous or crowded environments.
- Supporting 24/7 operation with consistent performance.

II. LITERATURE SURVEY

For our project we are surveying some reports and references which are helping us to make it easy and simplest and they are as follows

1. Quoc Khanh Dang , Young Soo Suh [2012]: “Human-following robot using infrared camera” The use of an infrared camera in humanfollowing robots enhances detection accuracy and tracking capabilities, especially in low-light conditions. A human-following robot using an infrared camera leverages thermal imaging to detect and track individuals based on their body heat. The robot's key components include an infrared camera to identify heat signatures, a microcontroller for processing, motors for mobility, and a control algorithm for smooth tracking.
2. 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 The study finds ultrasonic sensors effective for distance measurement and obstacle avoidance in human-following robots, but notes their sensitivity to environmental factors.
3. Mr Kumar and Mr Gupta,12 December [2013]: A “Smart Trolley using Arduino”, International Journal of Advanced Research in Computer Engineering & Technology (IJARCET). The Smart Trolley using Arduino effectively combines automation and user-friendly features, enhancing the shopping experience through real-time navigation and item tracking.
4. D.J.S.P.S. Dhavale Shraddha D [2016]: IOT Based Intelligent Trolley for Shopping Mall An IoT-based intelligent trolley in shopping malls enables real-time item tracking, automated billing, and personalized shopping experiences, enhancing efficiency and customer convenience.
5. S. M. Kalyani Dawkharet al[2022]: proposed Using Radio Frequency Identification (RFID) technology, an electronic shopping cart. This cart has a feature to keep track of the contents, like. Viewing the product name, expiration date, and price, they have employed a Liquid Crystal Display (LCD) screen to display the products. 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.

6. Hanooja T, Raji C.G and Sreelekha M in the year of [2020]: “Human Friendly Smart Trolley With Automatic Billing System” A HumanFriendly Smart Trolley with Automatic Billing System is an innovative solution designed to enhance the shopping experience by integrating technology into traditional shopping carts. Equipped with sensors, a barcode or RFID scanner, and a display screen, the smart trolley automatically scans items as they are placed into the cart. It calculates the total cost in real-time, eliminating the need for manual billing at checkout counters. Additionally, features like navigation assistance and integration with digital payment systems make it user-friendly.

7. 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 with Automatic Billing System using RFID and ZigBee is a cutting-edge technology aimed at revolutionizing the retail experience. The cart is equipped with RFID readers to automatically identify and record items as they are placed in or removed from the cart, ensuring accurate real-time billing.

8. S. K. Shankar, S. Balasubramani, S. A. Basha, S. Ariz Ahamed, and N. S. Kumar Reddy [2021]: “Smart Trolley for Smart Shopping with an Advance Billing System using IoT,” A Smart Trolley for Smart Shopping with an Advanced Billing System using IoT streamlines the shopping experience by automatically detecting items through IoT-enabled sensors and updating the bill in real-time.

III. METHODOLOGY

The system works by combining sensors, identification modules, motor drivers, and a robotic arm, all controlled by an Arduino Mega microcontroller. The system is designed to automatically navigate through predefined paths, identify items, and perform pick-and-place operations on shelves.

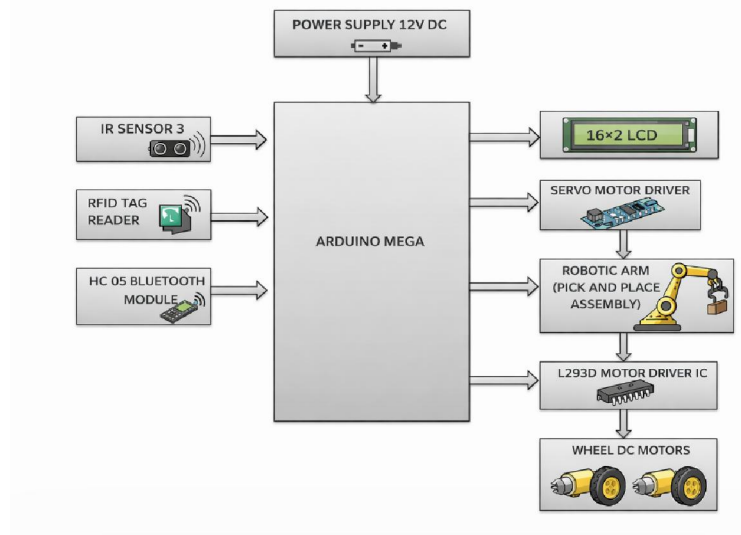


Fig. 1. Block Diagram

1. Power Initialization

The system is powered by a 12V DC rechargeable battery which supplies power to the Arduino Mega, sensors, motor drivers, and other modules. The Arduino acts as the central control unit that manages all operations.

2. Autonomous Navigation

The trolley moves along a predefined path using IR line follower sensors. These sensors detect the contrast between the line and the floor surface, allowing the robot to follow the path accurately.



3. Obstacle Detection

while moving, the system continuously checks for obstacles using IR or ultrasonic sensors. If an obstacle is detected, the Arduino stops the trolley temporarily to prevent collision.

4. Item Identification

when the trolley reaches a shelf location, the RFID tag reader scans the RFID tag attached to the item or shelf. The RFID reader sends the identification data to the Arduino, which determines the correct action for the item.

5. Communication and Control

The HC-05 Bluetooth module enables wireless communication with a smartphone or control system. This allows monitoring, manual control, or data transmission if required.

6. Display of Information

A 16×2 LCD display shows system information such as item identification, operation status, or movement commands.

7. Pick-and-Place Operation

once the item is identified; the Arduino sends signals to the servo motor driver which controls the robotic arm. The robotic arm moves toward the item, closes the gripper to pick it up, and then places it in the correct shelf location or trolley compartment.

8. Movement Control

The movement of the trolley is controlled by DC motors connected through the L293D motor driver IC. The motor driver receives control signals from the Arduino to move the trolley forward, backward, or stop.

9. Continuous Operation

After completing one task, the trolley continues following the path and repeats the process for other shelves or items until the operation is complete.

A. ARDUINO MEGA

The Arduino Mega 2560 is a powerful microcontroller board based on the ATmega2560 microcontroller. It is widely used in robotics, automation, and embedded system projects that require a large number of input/output pins. Compared to the Arduino Uno, the Mega provides more digital pins, analog inputs, and memory, making it suitable for complex projects such as autonomous robots, robotic arms, and smart automation systems.

Microcontroller: ATmega2560

Operating Voltage: 5V

Recommended Input Voltage: 7V – 12V

Input Voltage Limits: 6V – 20V

Digital Input/Output Pins: 54 pins

PWM Output Pins: 15 pins

Analog Input Pins: 16 pins

Flash Memory: 256 KB (8 KB used by bootloader)

SRAM: 8 KB

EEPROM: 4 KB



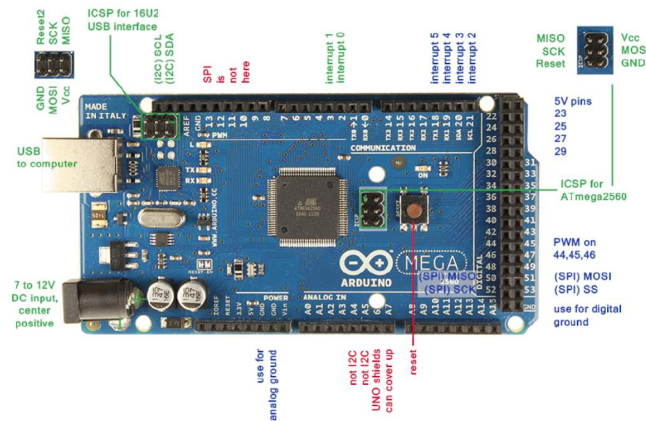


Fig. 2. Arduino mega

B. RFID Tag Reader:

The EM-18 RFID Reader is a commonly used 125 kHz RFID reader module designed to read RFID tags and transmit the tag ID to a microcontroller. It is widely used in access control systems, attendance systems, security systems, and automation projects.

Features:

- Operating Frequency: 125 kHz\
- Operating Voltage: 5V DC
- Current Consumption: 50 mA (approx.)
- Communication Output: UART (Serial) / Wiegand
- Reading Distance: 5 – 10 cm
- Data Output Rate: 9600 bps
- Compatible Tags: EM4001 / EM4100 RFID tags
- Interface Type: TTL Serial Interface

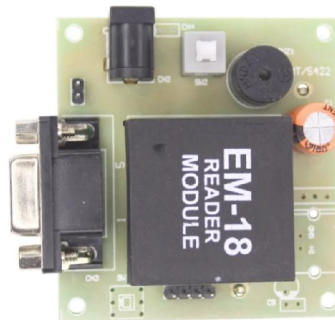


Fig. 3. RFID Tag Reader

C. HC05 Bluetooth Module:

A simple The HC-05 Bluetooth module is a wireless communication device used to transmit and receive data between microcontrollers and smartphones or computers. It uses Bluetooth Serial Communication (UART) to connect with devices.

- Bluetooth Version: Bluetooth v2.0 + EDR
- Operating Voltage: 3.3V – 6V



- Recommended Voltage: 5V
- Operating Current: 30 mA (approx.)
- Communication Interface: UART (Serial Communication)
- Default Baud Rate: 9600 bps



Fig. 4. HC05 Bluetooth Module

D. Robotic ARM:

A Robotic Arm with 6 Servo Motors is a mechanical manipulator used for pick-and-place operations in robotics projects. It consists of multiple joints controlled by servo motors that allow movement in different directions.

- Type: 6 Degree of Freedom (6 DOF) Robotic Arm
- Number of Servo Motors: 6
- Operating Voltage: 4.8V – 6V
- Control Signal: PWM (Pulse Width Modulation)
- Rotation Range: 0° – 180°
- Servo Motor Type: SG90 / MG995 / MG996R (depending on model)
- Gripper Mechanism: Mechanical claw controlled by servo motor
- Material: Acrylic / Aluminum / Plastic frame



Fig. 5. Robotic ARM

IV. CONCLUSION

The AutoShelf: Autonomous Trolley with Robotic Arm for Item Replacement project demonstrates an efficient and intelligent solution for automating the process of shelf management in environments such as supermarkets, warehouses, and libraries. The system combines autonomous navigation, item identification, and robotic manipulation to perform tasks that traditionally require human labour. Using a microcontroller-based control system, the trolley can follow predefined paths with the help of line-following sensors while ensuring safe movement through obstacle detection sensors. The integration of RFID or barcode scanning modules allows the system to identify products and manage their



placement accurately. The robotic arm with a gripper mechanism performs precise pick-and-place operations, enabling automatic restocking and item replacement.

This automation significantly reduces manual effort, improves operational efficiency, and increases accuracy in inventory management. The project also demonstrates the practical application of embedded systems, robotics, and automation technologies in modern retail and logistics environments. Overall, the AutoShelf system provides a strong foundation for future development in smart warehouse management and automated retail systems, contributing to the advancement of intelligent robotic solutions for real-world applications.

V. FUTURE SCOPE

The AutoShelf Autonomous Trolley with Robotic Arm has significant potential for further development and improvement. Future enhancements can make the system more intelligent, efficient, and suitable for real-world industrial applications.

1. Integration with Artificial Intelligence (AI)

AI algorithms can be used to recognize products using cameras and image processing, enabling the robot to identify items automatically without relying only on RFID or barcode scanners.

2. IoT-Based Inventory Monitoring

The system can be connected to the Internet of Things (IoT) platform to monitor stock levels in real time. Data can be sent to a cloud server where managers can track inventory and receive alerts when items are low.

3. Camera-Based Navigation

Instead of line-following sensors, the trolley can use computer vision and cameras for navigation. This will allow it to move freely in the environment and adapt to changes in the layout.

4. Multiple Robot Coordination

In large warehouses or supermarkets, multiple AutoShelf robots can work together to manage shelves efficiently. Communication between robots can improve speed and reduce workload.

5. Mobile Application Control

A mobile or web application can be developed to control the robot, monitor its status, and schedule restocking operations remotely.

6. Improved Robotic Arm Design

The robotic arm can be enhanced with additional degrees of freedom and stronger grippers to handle different types of products more accurately.

ACKNOWLEDGMENT

It gives us great pleasure in presenting the paper on “Autoshelf: Autonomous trolley with robotic arm for item replacement”. We would like to take this opportunity to thank our guide, Prof. Vilas S. Ubale, Professor, Department of Electronics & Computer Engineering Department, Amrutvahini College of Engineering, Sangamner, for giving us all the help and guidance we needed. We are grateful to him for his kind support, and valuable suggestions were very helpful.

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