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Artificial Intelligence Based Library Management System

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Abstract

This paper presents an Artificial Intelligence (AI) based automated library management system integrated with a robotic book pick and place mechanism. The system utilizes RFID/barcode scanning, sensors, microcontrollers, and robotic navigation to automate book handling operations such as sorting, placement, and retrieval. The system also incorporates overload detection, shelf identification using QR codes, and AI-based chatbot assistance. The proposed system reduces manual workload, improves accuracy, and enhances overall efficiency in modern libraries.

Keywords: Artificial Intelligence, RFID, Robotics, Library Automation, Io

1. Introduction

Libraries are essential knowledge repositories, but conventional management relies on manual processes such as cataloging, issuing, returning, and shelving. These activities are time-consuming, prone to human error, and difficult to scale with increasing collections.

Recent advances in Artificial Intelligence (AI), Internet of Things (IoT), and robotics enable the transition to smart libraries. AI supports intelligent search and decision-making, IoT ensures real-time connectivity, and robotics automates physical handling of books.

The proposed system integrates these technologies to automate repetitive tasks. Barcode/RFID ensures accurate identification, sensors enable navigation and safety, and a robotic arm performs precise pick-and-place operations. The system reduces manpower, minimizes errors, improves turnaround time, and enhances user experience with faster book access and reliable tracking.

2. Objectives

- Study and analyze required hardware and software components.
- Design an autonomous robot for book handling.
- Integrate barcode/RFID system with database.
- Develop navigation and placement mechanism.
- Reduce manual effort and increase efficiency.

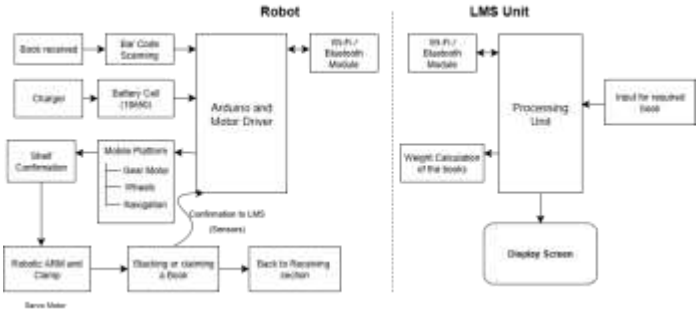
3. Literature Survey

Prior work demonstrates RFID-based tracking to improve inventory accuracy and reduce losses. Arduino/ESP32-based robots with IR and ultrasonic sensors have been used for line-following navigation and obstacle avoidance. Some systems employ camera-based navigation (e.g., OpenCV) for locating books, while IoT platforms enable cloud databases and real-time monitoring.

Autonomous robots with grippers have been implemented for book retrieval and return, integrating user interfaces for search and request handling. However, many systems lack safety features (payload monitoring), robust shelf confirmation, and intuitive user interaction. This work extends existing approaches by integrating barcode/RFID identification, QR-based shelf localization, overload detection, and AI-assisted search within a unified architecture, improving reliability, safety, and usability.

4. Methodology

The proposed system consists of multiple modules including input system, processing unit, communication module, robotic platform, and database system.



The robot navigates using line-following sensors and detects shelves using QR codes. The processing unit manages all operations and updates the database in real-time.

5. System Working

A) Book Stacking Process:
When a book is returned, it is scanned using a barcode scanner. The system identifies the correct shelf and sends commands to the robot. The robot navigates to the shelf and places the book using a robotic clamp.

B) Book Retrieval Process:
When a user requests a book, the system identifies its location and commands the robot. The robot retrieves the book and delivers it to the user.

C) Overload Indicator:
The system calculates total weight of books. If it exceeds the limit, an alert is generated to prevent damage.

D) Shelf Identification:
Each shelf has a QR code. The robot scans it to confirm correct placement.

6. Equipment Details

The system uses the following components:

• Arduino UNO : Microcontroller (ATmega328P) serving as the control unit; interfaces sensors, motors, and communication modules; executes control logic.
• Motor Driver (L298N) : Provide high torque at low speed for base movement; gear reduction improves load-carrying capability.
• Geared DC Motor (3kg-cm torque) : Provide high torque at low speed for base movement; gear reduction improves load-carrying capability.
• AC to DC Adapter : Power source for mobility and electronics; regulated supply ensures stable operation; charger maintains battery health
• Bluetooth Module (HC-05) : Serial wireless link between controller and host (or app) for command/data exchange.
• IR Sensor : IR-based reflective sensors detect track contrast; used for path following and alignment.
• RFID Scanner : : Reads unique identifiers on books/shelves; links physical items to database records for accurate tracking.
• Robotic Clamp : Mechanical end-effector with gripper; grips books securely for pick-and-place.

• Wheels : Provide mobility and stability; selected diameter and material ensure traction and smooth motion.

Each component plays a vital role in navigation, sensing, and actuation of the robotic system.

7. Algorithm for Library Management System

1. Start
2. User Login (verify credentials)
3. Book Search (semester/subject wise)
4. Display book list
5. Add books to cart
6. Check weight limit
7. Generate overload warning if needed
8. Request/reserve book
9. Logout
10. Stop

8. Load Calculation and Motor Selection

Total Robot Unit mass= 7kg +3 kg load

$$M_r=10 \text{ Kg}$$

Coefficient of rolling friction, $U_r=0.05$

Wheel radius, r = 6 cm = 0.06m

Desired acceleration a = 0.5 m/sec^2

Total force required = 9.905 N

Torque and speed calculation:

T_{total} = 0.5943 Nm

T_{motor}= 0.1486 Nm

Safety factor =1.5

Required torque, T_{req} = 0.223Nm

Converting Nm into Kg cm

Required Torque, T_{req} = 2.27kgcm

Selecting motor with required Torque Rating = 3 Kg cm

This ensures safe and efficient operation.

10. Results and Discussion

The system successfully automates library operations. It reduces human effort, increases accuracy, and improves efficiency. The addition of AI chatbot and overload system enhances usability and safety.

11. Conclusion

The AI-based library management system provides an effective solution for automating traditional libraries. The integration of robotics and intelligent systems improves efficiency and reduces errors. Future work includes real-time tracking and advanced AI integration.

12. Future Scope

The proposed system can be further enhanced by integrating advanced Artificial Intelligence algorithms for predictive book demand and automated inventory management. Real-time tracking using IoT and cloud-based databases can improve system scalability and accessibility. The robotic system can be upgraded with computer vision for more accurate object detection and autonomous navigation without predefined paths. Additionally, voice-based user interaction and mobile application integration can enhance user experience. Future improvements may also include multi-robot coordination for handling larger libraries efficiently and reducing operation time significantly.

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