RV College of Engineering

Experiential Learning Report

Project-Based Learning

2024-25

Title of the Project

[Automated Book Sorting System with Robotic arm Integration]

Student(s)

USN	Name
1RV24IS097	PRIYANSH SHUKLA
1RV24CS019	ADVIK AGGARWAL
1RV24CS025	AKSHAT KAWARIA
1RV24IM007	ATHARVA SOMANI

Mentor

Name, Designation & Department
Dr. Nivya Muchikel Mathematics Department

1. Introduction

In modern libraries, the process of returning and re-shelving books manually can be time-consuming and prone to human error. To solve this problem, our project introduces an automated book sorting system using a mobile rover integrated with a robotic gripper. The system is designed to function as follows: The robotic gripper then picks up the book from the returned section and places it onto the slot of the rover. The rover navigates through the library to reach the appropriate shelf. Once it arrives, the gripper carefully places the book on the shelf. This mobile approach not only improves efficiency and accuracy but also offers scalability, adaptability, and cost-effectiveness. It is particularly suitable for smart library systems aiming to modernize their operations through practical, student-built automation. The robotic arm is capable of gripping, lifting, and placing books using servo motors, and is mounted on a rover platform.

2. Problem Definition

- In large libraries and academic institutions, managing and organizing physical books is a time-consuming and error-prone task. Librarians often spend significant time locating the correct shelves and placing books manually. This becomes inefficient, especially when dealing with high volumes of returned books or reorganizing collections.
- There is a need for an automated system that can reduce human effort by autonomously transporting books from a central collection point to their respective shelves and accurately placing them without manual intervention.
- This project proposes a solution using a mobile rover integrated with a robotic arm, capable of navigating a pre-defined path, stopping at the correct shelf, and placing books using a servo-controlled gripper. The system uses hardcoded path logic for navigation and synchronizes robotic arm actions to mimic intelligent placement behavior.

3. Objectives

- To design and develop a mobile rover that can follow a predefined path and reach specific shelf locations accurately.
- To integrate a robotic arm with the rover capable of picking a book placed on the rover and placing it onto a designated shelf.
- To synchronize the movement of the rover and the robotic arm such that book placement is performed efficiently at the right time and location.
- To minimize human effort in routine library operations by automating the task of transporting and placing books.
- To demonstrate a low-cost prototype that can be scaled for real-world use in educational institutions and public libraries.

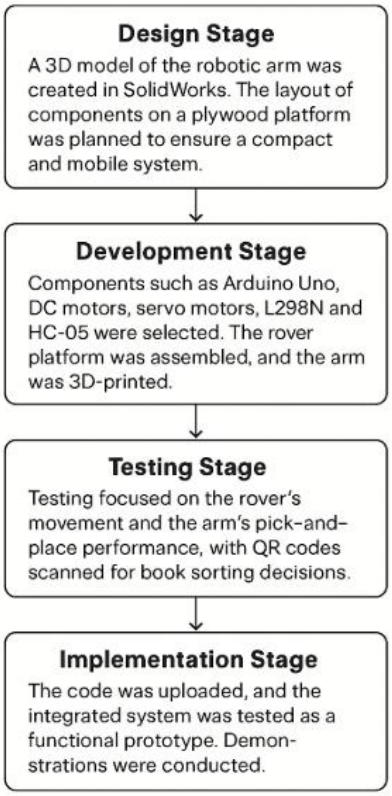
4. Methodology

Design Stage: In the design stage, a 3D model of the robotic arm was created using SolidWorks to visualize the movement, reach, and integration of joints. The layout of the components on the wooden platform—including the arm, motors, sorting slots, and electronics—was planned to ensure stability and functionality. The system was designed to be compact and mobile, eliminating the need for fixed infrastructure like conveyor belts.

Development Stage: During this stage, essential components were selected, including the Arduino Uno, DC motors, MG996R and SG90 servo motors, L298N motor drivers. The wooden rover platform was assembled, and wiring was completed using jumper wires and a breadboard. The robotic arm was 3D-printed and mounted centrally for balance and optimal reach to both pickup and slot areas.

Testing Stage: Testing focused on verifying the rover's movement, turning accuracy, and the arm's pick-and-place performance. Servo angles were calibrated to ensure proper gripping, lifting, and releasing of books into a single fixed slot. Appropriate sorting decisions were manually done for precise book placement. Any issues related to servo alignment, motor imbalance, or timing delays were identified and rectified.

Implementation Stage: In the final stage, all hardware and software components were integrated into a single working system. The Arduino IDE was used to upload code that coordinated rover motion with arm control. Demonstration trials were conducted, showcasing the system's ability to sort books into slots and deliver them to shelves. The final prototype reflected a low-cost, scalable, and mobile solution for automating book sorting in libraries.



5.Project Execution

The execution of the project involved the seamless integration of mechanical design, embedded systems, and wireless control to automate the book-picking and placement task using a robotic arm mounted on a mobile rover. Initially, a compact wooden platform was constructed to serve as the rover base. Four DC motors, driven through two L298N motor driver modules, were attached to the wheels for forward, reverse, and turning movements. The control system was powered by an Arduino Uno, acting as the brain of the entire system.

A 3-degree-of-freedom robotic arm was mounted centrally on the rover. It was built using 3D-printed parts and operated using MG996R servo motors for base rotation, shoulder, and elbow movement, and an SG90 servo motor for operating the gripper mechanism. A servo driver module ensured stable PWM control from the Arduino to all servo motors.

During trials, different input codes were tested to verify the responsiveness of the system and the alignment of servo motors. Fine-tuning of servo angles and rover motion ensured smooth operation without collisions. The prototype was successfully able to demonstrate book retrieval, transportation, and placement using minimal manual intervention, achieving the core objective of partial automation in library book management.

6.Tools and Techniques Used

- Arduino Uno – Central control unit
- DC Motors (×4) – Movement of rover wheels
- L298N Motor Drivers (×2) – Controls speed and direction of 4 DC motors
- MG996R Servo Motors (×3) – Moves base, shoulder, and elbow of the robotic arm
- SG90 Servo Motor (×1) – Operates the gripper to grip and release books
- Servo Driver Module – Provides PWM control to servo motors from Arduino
- HC-05 Bluetooth Module – Enables wireless communication with mobile device
- Breadboard & Jumper Wires – Temporary circuit connections during development
- Wheels (×4) – Attached to motors for rover movement
- Mobile QR/Barcode Scanner – Scans book code and sends sorting info to Arduino
- 3D Printed Robotic Arm Parts – Mechanical structure of the arm for sorting books

7. Results and Discussion

The project was executed as a standalone embedded system that automates the process of picking and placing books using a robotic arm mounted on a mobile rover platform. The system operates entirely on pre-programmed instructions written in Arduino IDE, without the use of wireless communication or scanning devices.

To begin, a stable plywood platform was prepared to act as the mobile base. Four DC motors were attached to the base and controlled using two L298N motor driver modules, providing directional movement to the rover. The entire system was controlled by an Arduino Uno, which served as the main controller.

The robotic arm was constructed using 3D-printed components and was mounted centrally on the base for balanced weight distribution. The arm consisted of three MG996R servo motors that controlled base rotation, shoulder, and elbow movement. An SG90 servo motor was used to operate the gripper for picking up and releasing books. A servo driver module was used to supply PWM signals from the Arduino to all servo motors efficiently.

All movement sequences, including the rover's motion and robotic arm's pick-and-place actions, were programmed directly into the Arduino. The system follows a fixed logic sequence: move to the pickup location, grip the book, rotate to the designated slot, and release the book. No real-time external input is required during execution.

During testing, multiple iterations were run to calibrate the servo angles and verify movement timing. Adjustments were made to fine-tune arm positioning and ensure consistent book handling. The final working model demonstrated successful autonomous operation based purely on predefined instructions, achieving a low-cost and simplified solution for book-sorting automation without requiring Bluetooth or scanning technologies.

8. Prototype (Hardware/Software)

The prototype developed for the automated book handling system consists of both mechanical and electronic components integrated through embedded programming. The entire process is based on predefined logic written in the Arduino IDE, eliminating the need for external input such as Bluetooth or scanning systems.

- **Hardware Prototype**

The hardware assembly consists of a wooden mobile platform driven by four DC motors connected to two L298N motor driver modules. An Arduino Uno microcontroller forms the central control unit, coordinating both the rover's movement and the robotic arm's actions. The robotic arm includes three MG996R servo motors that manage base rotation, shoulder, and elbow motion, while an SG90 servo motor controls the gripper.

The mechanical parts of the robotic arm were designed using SolidWorks and fabricated using 3D printing to ensure lightweight and precise motion. A servo driver module was incorporated to provide stable PWM signals and avoid voltage drops during simultaneous motor operations. All connections were made using a breadboard and jumper wires for flexibility and easy modifications.

- **Software Prototype**

The control logic was developed using the Arduino IDE . No external control (e.g., Bluetooth or mobile app) was implemented; instead, the system runs a hardcoded sequence of actions. These include navigating to a fixed pickup location, activating the gripper to lift a book, rotating the arm to the designated slot, and releasing the book.

Servo motor angles and motor timing were manually calibrated to ensure accuracy and synchronization between rover movement and arm operation. Real-time serial monitoring was used during testing for debugging and fine-tuning.The prototype successfully demonstrates a standalone, low-cost automated book handling system designed for structured environments like libraries or academic archives.

9.Challenges Faced

1) Maintaining Stable Movement of the Rover:
Ensuring the rover moves in a straight line without drifting was challenging due to uneven moto speeds and surface friction.

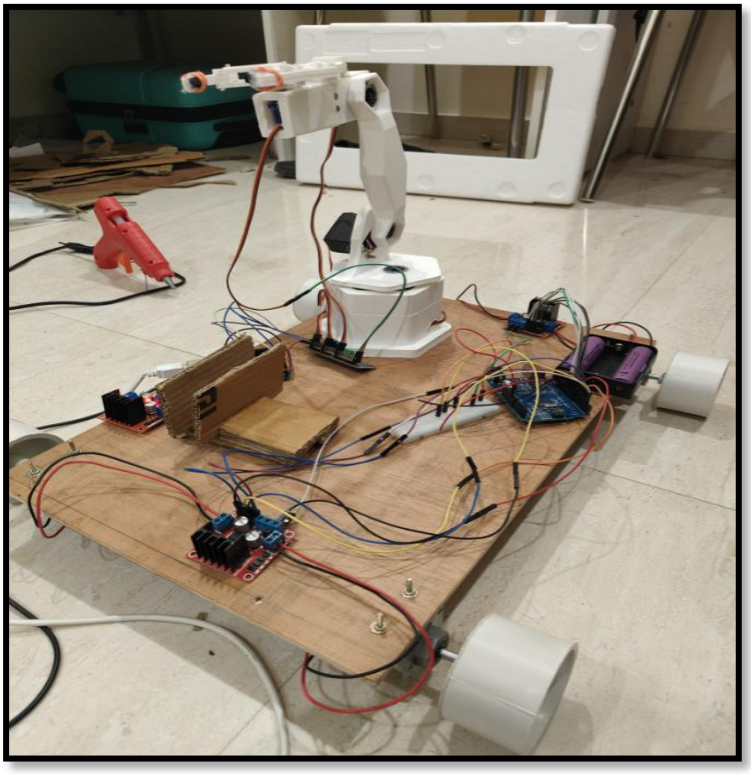
2) Power Management for Dual Motor Drivers:
Running four motors simultaneously required careful power distribution, and power drops occasionally affected speed consistency.

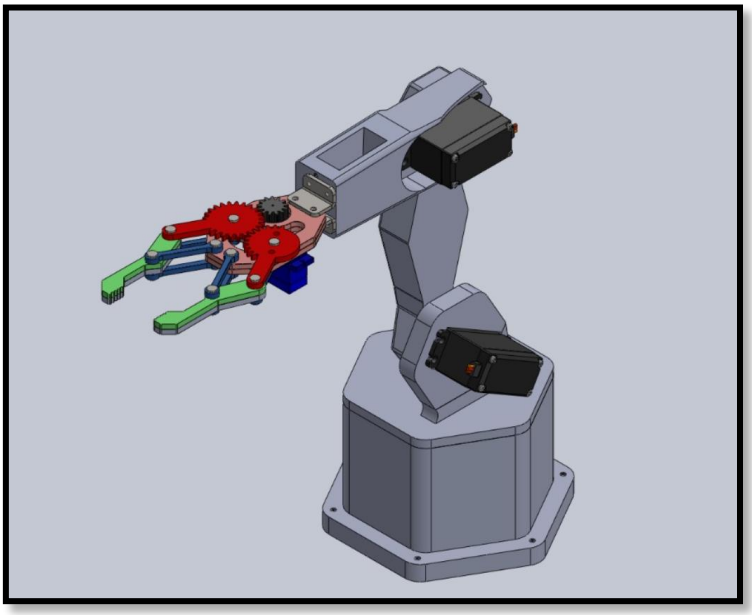
3) Servo Angle Calibration for Arm Movement:
Fine-tuning the servo angles to ensure the arm reaches the shelf position accurately took multiple iterations and testing.

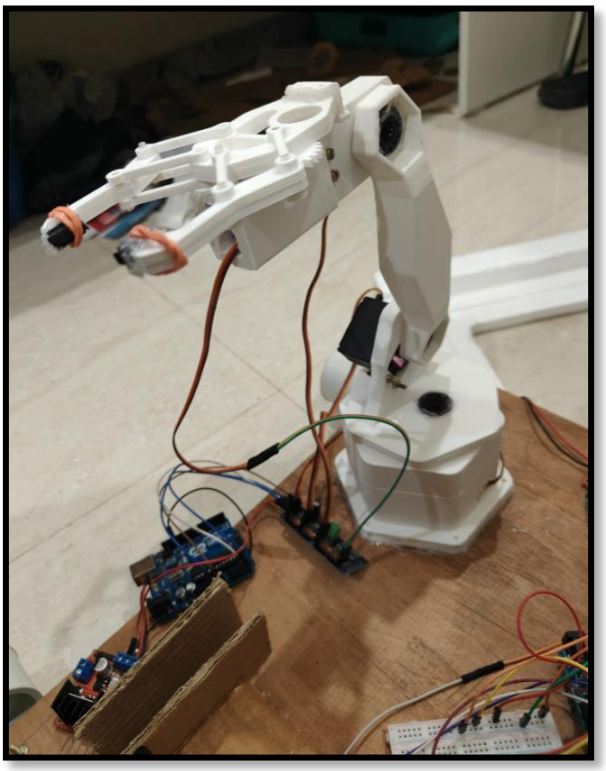
4) Gripper Adjustment for Different Book Sizes:
Designing a gripper that can hold books of varying thickness securely without damaging them was a mechanical challenge.

5) Timing Synchronization Between Rover and Arm:
Coordinating the rover's stopping position with the arm's pick-and-place actions without using sensors required precise delay-based programming and trial-and-error.

10, Visuals and Images







11,Conclusion:

This project presents a functional and compact prototype for automating basic book handling tasks using a single-platform mobile rover integrated with a 3D-printed robotic arm. The system effectively performs book pickup, storage in a designated slot, transportation, and shelf placement with autonomous navigation. Manual inputs are used to simulate real-world book returns, and the arm executes reliable pick-and-place operations using servo motors. The rover's movement and arm control were successfully programmed using Arduino, demonstrating smooth coordination between mechanical and electronic components. Overall, the system meets its core objectives and the design is low-cost, modular, and easy to operate, making it ideal for educational purposes and small-scale library automation

12.References

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13.QR Code of Demonstration Video