LIBERBOT: SMART LIBRARY ASSISTANT

A Project Report

Submitted by

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to

APJ Abdul Kalam Technological University

in partial fulfillment of the requirements for the award of the Degree of

Bachelor of Technology (B.Tech)

in

ROBOTICS & AUTOMATION ENGINEERING

Under the guidance of

MR. ARJUN K M

JYOTHI ENGINEERING COLLEGE

LEAD KINDLY LIGHT

TET

CREATING TECHNOLOGY
LEADERS OF TOMORROW
ESTD 2002

DEPARTMENT OF ROBOTICS & AUTOMATION ENGINEERING

Jyothi Engineering College
Reaccredited with NAAC (Grade A) and NBA Programmes*
Approved by AICTE and Affiliated to APJ Abdul Kalam Technological University
A CENTRE OF EXCELLENCE IN SCIENCE AND TECHNOLOGY BY THE CATHOLIC ARCHDIOCESE OF TRICHUR
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*NBA reaccredited BTech Programmes in Civil Engineering, Computer Science and Engineering, Electronics and Communication Engineering, Electrical and Electronics Engineering and Mechanical Engineering valid till 2025.

April 2025

DECLARATION

We the undersigned hereby declare that the project report "LiberBot: Smart Library Assistant", submitted for partial fulfillment of the requirements for the award of degree of Bachelor of Technology of the APJ Abdul Kalam Technological University, Kerala is a bonafide work done by us under supervision of Mr. Arjun K M. This submission represents our ideas in our own words and where ideas or words of others have been included, we have adequately and accurately cited and referenced the original sources. We also declare that we have adhered to ethics of academic honesty and integrity and have not misrepresented or fabricated any data or idea or fact or source in this submission. We understand that any violation of the above will be a cause for disciplinary action by the institute and/or the University and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been obtained. This report has not been previously used by anybody as a basis for the award of any degree, diploma or similar title of any other University.

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Date:

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CREATING TECHNOLOGY LEADERS OF TOMORROW

ESTD 2002

CERTIFICATE

This is to certify that the report entitled " **LiberBot: Smart Library Assistant** " submitted by ANNMARY SHAJI(JEC21RA004), ANSAB C.K(JEC21RA005), NITHIN B(JEC21RA010), SEBIN IGNATIOUS(JEC21RA014) to the APJ Abdul Kalam Technological University in partial fulfillment of the requirements for the award of the Degree in Bachelor of Technology in **Robotics & Automation Engineering** is a bonafide record of the project work carried out by them under my/our guidance and supervision. This report in any form has not been submitted to any other University or Institute for any purpose.

Internal Supervisor	**Head of the Department**
Mr. Arjun K M **Assistant Professor**	**Dr. C Karthik** **Associate Professor**

ACKNOWLEDGEMENT

We take this opportunity to thank everyone who helped us profusely, for the successful completion of our project work. With prayers, we thank **God Almighty** for his grace and blessings, for without his unseen guidance, this project would have remained only in our dreams.

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VISION OF THE INSTITUTE

Creating eminent and ethical leaders through quality professional education with emphasis on holistic excellence.

MISSION OF THE INSTITUTE

- To emerge as an institution par excellence of global standards by imparting quality Engineering and other professional programmes with state-of-the-art facilities.
- To equip the students with appropriate skills for a meaningful career in the global scenario.
- To inculcate ethical values among students and ignite their passion for holistic excellence through social initiatives.
- To participate in the development of society through technology incubation, entrepreneurship and industry interaction.

VISION OF THE DEPARTMENT

To be a pioneer in robotics and automation education and create distinguished and ethical leaders committed to the profession and society via quality education, research and development.

MISSION OF THE DEPARTMENT

- To provide students with opportunities to become leaders in robotics and automation education and research by facilitating learning, exposure, and skill.
- To provide a high-quality education that will result in graduates who are both professional and socially committed
- To instil long-term skills in automation technologies, research and learning mindsets, and societal values in students

PROGRAMME EDUCATIONAL OBJECTIVES

PEO 1: Graduates will have a basic and deep understanding of various engineering concepts in order to build, analyse, and develop systems to solve real-world challenges using Robotics and Automation.

PEO 2: Graduates are equipped with cutting-edge technology to design and build unique solutions using current tools, resulting in lifelong learning or improved skills, allowing them to become experts in their profession.

PEO 3: Graduates will be trained in multidisciplinary technologies to support societal innovation, creativity, and entrepreneurship.

PROGRAMME SPECIFIC OUTCOMES

On the completion of Robotics and Automation program, the students will possess:

PSO 1: An ability to analyse Automation systems/problems and recommend relevant technology for a more productive industrial ecosystem.

PSO 2: An ability to Model, simulate, and design automation for increased industrial yield using engineering skills.

PSO 3: An ability to explain and resolve problems in factory automation, create indigenous systems using current tools.

PSO 4: An ability to develop robotics and automation engineering applications to solve human problems.

PROGRAMME OUTCOMES

1. **Engineering knowledge:**Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. **Problem analysis:** Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. **Design/development of solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. **Conduct investigations of complex problems:** Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. **Modern tool usage:**Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
6. **The engineer and society:**: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7. **Environment and sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
9. **Individual and team work:** Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
10. **Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
11. **Project management and finance:** Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
12. **Life-long learning:** Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

COURSE OUTCOMES

COs	Description
RAD415.1	Model and solve real world problems by applying knowledge across domains (Cognitive knowledge level: Apply).
RAD415.2	Develop products, processes or technologies for sustainable and socially relevant applications (Cognitive knowledge level: Apply).
RAD415.3	Function effectively as an individual and as a leader in diverse teams and to comprehend and execute designated tasks (Cognitive knowledge level: Apply).
RAD415.4	Plan and execute tasks utilizing available resources within timelines, following ethical and professional norms (Cognitive knowledge level: Apply).

CO MAPPING TO POs

	POs											
COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
RAD415.1	2	2	2	1	2	2	2	1	1	1	1	2
RAD415.2	2	2	2	-	1	3	3	1	1	-	1	1
RAD415.3	-	-	-	-	-	-	-	-	3	2	2	1
RAD415.4	-	-	-	-	2	-	-	3	2	2	3	2
RAD415.5	2	3	3	1	2	-	-	-	-	-	-	1
RAD415.6	-	-	-	-	2	-	-	2	2	3	1	1
Average												

CO MAPPING TO PSOs

	PSOs			
COs	PSO1	PSO2	PSO3	PS04
RAD415.1	2	2	-	-
RAD415.2	3	1	-	-
RAD415.3	-	-	2	-
RAD415.4	-	3	1	-
RAD415.5	-	-	2	3
RAD415.6	3	-	1	-
Average	1.3	1	1	0.5

ABSTRACT

Libraries often struggle with organizing and retrieving books efficiently, leading to delays and misplaced books. LiberBot is a smart solution that automates book retrieval and reshelving using an XY robotic system mounted on an aluminum T-slot frame. With a coordinate-based tracking system, it accurately finds, picks, and places books, making the process faster and more organized. This project aims to reduce manual effort, improve book accessibility, and make library management more efficient. It combines hardware and software components, using Python and C programming for control and Autodesk Fusion 360 for 3D modeling and simulation. This robotic system ensures smooth, precise movement, minimizes errors and speeds up retrieval. LiberBot makes libraries smarter, faster, and more user-friendly, saving time and reducing workload.
Keywords: *Automation, XY Cartesian Mechanism, Stepper Motors, Arduino Mega 2560, Book Retrieval, Library Management, CNC Shield, A4988 Stepper Driver, L298N Motor Driver, Push-Button Interface, Precision Movement, Library Automation*

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CHAPTER 1

INTRODUCTION

Libraries often face challenges in organizing and retrieving books efficiently, leading to delays and misplacements. LiberBot is a book retrieval and reshelving system utilizing a Cartesian XY robotic mechanism for precision. It includes improved motor control algorithms for smoother movement, enhanced gripping for different book, and refined coordinate mapping for accuracy. A push-button interface and LCD display allow seamless user interaction. Powered by an Arduino Mega 2560 with stepper and DC motors, it streamlines book handling, reducing manual effort and retrieval time. It enhances library efficiency, making book management faster, more accurate, and user-friendly.

1.1 Problem Statement

Traditional libraries do have challenges in books organizing, retrieving, and reshelving correctly. Manual handling is time-consuming and are prone to errors, which leads to misplaced books and delays. In large public libraries it is more difficult to manage these large collections of books. LiberBot addresses this issue by automating the book retrieval and reshelving process using an XY robotic system which reduces manual effort by minimizing errors and improving the overall efficiency in library management.

1.2 Solution

The proposed Library Automation System is intended to redesign library operations with Cartesian robots to extract books from the shelves and mobile robots to transport them to the readers themselves. This new approach not only makes the book retrieval process but also allows librarians to focus on providing tailored service and support to patrons. By automatically performing this work, the system asserts to enhance the overall efficiency of library services, reducing users' waiting times, and increasing accessibility, ultimately resulting in a increasingly participatory and interactive library space.

1.3 Goals and Objectives

The main goal of this project is to create an autonomous library automation system with an XY Cartesian robotic mechanism for automated book reshelving and retrieval**.** The system has a custom-designed shelf with special sections, and an aluminum T-slot frame holds the Cartesian robot. The robot travels horizontally and vertically to fetch books through a coordinate-based tracking system. Equipped with precision grippers, the robot grasps books securely and places them in the right position, offering accurate reshelving and retrieval.

With less manual effort, error reduction, and greater accessibility, the system achieves library efficiency at its best. Additionally, a user-friendly interface facilitates easy book requests, optimizing the overall library experience.

1.4 Scope of the Project

This project is about the extbfend-to-end development of text bf LiberBot from text bf conceptualization, design, prototyping, testing, and final implementation. It is about the textbfintegration of an XY Cartesian robotic system with a structured shelving mechanism to enable textbfautomated book retrieval and reshelving using a textbfcoordinate-based tracking system.

The system is designed for textbfinstallation in libraries, archives, and documentation centers, where the handling of books needs to be automated. The project further entails an evaluation of the feasibility of embracing textbfrobotic automation into existing library infrastructures with textbfscalability and adaptability to meet future automation developments in storage and retrieval systems.

CHAPTER 2

LITERATURE SURVEY

This segment of the project is focused on a review of the literature on past research and development on library automation and book management systems using robots. Chapter Two will include some studies, their objectives, methodologies, and challenges related to automated reshelving and retrieval of books. The projects illustrated here are not similar to LiberBot, yet they have core technological strategies and automation methods that provide lessons useful in the maximization of our system's design, implementation, and integration into library systems.

2.1 Library Automation in University: A Literature Review

The library is a dynamic entity that requires constant positive fine-tuning to address the issue of its users. The innovation and emergence of computers brought about a definite transformation in the public. Along these lines, mechanisation has turned into the need of great importance. Library computerisation not only enhances the picture of the library and staff, in addition furnishes extra administrations to the users with the current staff. Library automation in simple terms is the use of PCs and the use of PC based things and organizations for doing various library exercises and limits. This research illustrates a literature review on Library Automation in University and related works of the topic. Apart from the library automation literature in the university libraries, the aspects of the study includes library orientation programme, comparative Study of library software, integrated library systems, libraries, image analysis, imaging systems, universities libraries, information storage and retrieval systems, information science, open source software, Information resources management, digital library system, Library and internet users, library administration, library use studies. Lastly, it presents the literature published on library automation in the university libraries, staff attitude towards on library automation, staff opinion on library automation, users' view regarding automation of library and need for orientation program in the university libraries. It also talks about the impact of the automation on library workers and users services, development and utilization of electronic resources.

2.2 Autonomous Robot for Inventory Management in Libraries

This paper suggests an autonomous robot to decrease labor, maximize productivity of in-hand inventory management systems and come up with a solution to build an automated inventory. Running a college library is under inventory management. Much like an inventory management system, it also faces problems with the number of books available. For instance, when a book becomes returned, the database is refreshed and indicates that the book does exist, but the book itself is not there in its place. because it is not present. The time and effort of the librarian are wasted as the books have to be placed back to its location. These problems are solved by designing an inventory management robot that is used in a library to put the returned books back to its location. The books which are returned are shelved in the robot's shelves. The robot reads the Radio Frequency Identification (RFID) tag of books to obtain the shelf position of the books and then finds its way into the library to the area where the book should be and places the book on its shelf thus placing the book readily available. The breakthrough of this system is that since it runs on a known system, it doesn't run on advanced SLAM methods, thereby decreasing the complexity of the system while being relatively flexible. This implementation too does not require any significant changes to be made to its environment.

2.3 LibRob: An Autonomous Assistive Librarian

This study investigates how new robotic systems may help li- library patrons effectively locate the book they require. A survey conducted among students of Imperial College there has been a lack of a time-efficient and methodical ways of locating the books they require in the col- lege library. The automated support solution used, LibRob, is a robot. itive robot that gives advice to the users in finding the book they are seeking in an interactive way to provide a more satisfactory ex- experience. LibRob is able to process a search query through voice or by text and obtain a list of suitable books by author, subject or title. Once the user selects the desired book, LibRob guides them to shelf containing the book, then returns to its base station on comple- ation. Experimental evidence suggests that the robot minimizes the time necessary to find a book by 47.4 percentage, and left 80 percentage of the users satisfied with their experience, showing that human-robot interactions can really enhance the effectiveness of basic activities in a library setting.

2.4 Experimental Robustness Evaluation of PID Controller for Position Control of a Cartesian Robot

The research presents the experimental robustness testing of a PID controller for position control of a Cartesian robot. It emphasizes the reliability of PID controllers in providing accurate position control, allowing smooth and accurate robotic movement in automation. The research also tests the robustness of the controller under different conditions, demonstrating its stability and responsiveness in automated systems. Moreover, the application of PID tuning techniques effectively minimizes positioning errors, which is essential in applications such as LiberBot, where book retrieval and reshelving should be accurate. The research emphasizes the practical application of PID control in robotic automation, which justifies its applicability in projects involving library automation. The research also offers insightful information on controller tuning techniques, which can improve the accuracy and efficiency of LiberBot's Cartesian robotic system. The insights justify the application of PID control in automating book handling operations, ensuring smooth movement and accurate book placement in libraries.

2.5 Gantry Robot System Checkers Player

Technological innovation in commodity movement is on the increase exponentially. Industrial activities in industries such as the automotive, healthcare industry, and even domestic uses the Pick and Place technology for production. It has been proven, for a long time has improved the Pick and Place system for other sectors, particularly how this process can be combined with AI. As a result of this, there has been a lot of research on how to make robots play games with their own minds. Most of the game development for AI is board games such as chess, Checkers, Tic Tac Toe, and other board games. Therefore, in this paper, we shall illustrate how to design a robot that is capable of playing board games. With gantry robot system, the robot will be programmed to play the game of Checkers by integrating the robot using the current AI checker. The concept with this robot is to apply Checkers AI and machine integration with a camera where the robot will compete with humans, the camera will detect it from the game board, and then with the experience of learning from AI, the robot can discover where to move the pieces and it is hoped that the motor will move according to the AI output command of the Checkers Robot. Then the robot will move back to its starting position and wait for its turn.

2.6 Model-Based Design Approach for Cartesian Robot Using Computed Torque Control

This research on the Model-Based Design Approach for Cartesian Robot Using Computed Torque Control explores the use of computed torque control (CTC) to improve the precision of motion in Cartesian robots. The work emphasizes the use of a model-based approach to enhance system response through compensation for nonlinear dynamics and external disturbances. By using CTC, the Cartesian robot realizes smoother motion, increased stability, and less tracking error, making it applicable in precision positioning applications. These results are applicable to LiberBot because they give a systematic method of enhancing the precision and effectiveness of book retrieval tasks. Using computed torque control integrated into LiberBot's design is capable of optimizing its ability to move through the shelves, correctly pick the books, and place them with negligible mechanical fault, providing seamless library automation.

2.7 Research on Automatic Classification of Documents in Library Environment: A Literature Review

This paper aims to provide an overview of automatic classification research, addressing issues of the automatic classification of documents in a library environment. The review has been conducted on literature that has been published in mainstream library and information science literature. The review was carried out on literature that has been published in academic and professional LIS journals and other documents. This survey shows that basically three types of research are being conducted on automatic classification:

1) Hierarchical classification using different library classification schemes.

2) Document categorization and text categorization using different type of classifiers with or without utilizing training documents.

3) Automatic bibliographic classification where majority of the work is focused towards solutions to the problems of organization of electronic documents in an online environment.

CHAPTER 3

METHODOLOGY

LiberBot is developed using a Cartesian X-Y robotic system for automated book retrieval. The design phase includes 3D modeling in Fusion 360 to optimize component placement. The structure is built using an aluminum T-slot frame with linear rails for smooth motion. NEMA 17 stepper motors, controlled via A4988 drivers and an Arduino Mega 2560 with a CNC Shield, enable precise movement. A push-button interface and a 16x2 LCD facilitate user input. The forklift mechanism retrieves books using coordinate-based positioning. Testing and refinement ensure system reliability, accuracy, and efficiency in book retrieval and reshelving operations.

3.1 System Design

The system is implemented as an automatic book pick-up and replacement mechanism with a combination of hardware and software elements to be operated in precise and effective manners. As its backbone, the Cartesian X-Y robot is mounted on a C-clamped shelf, which provides structural integrity in traveling across the target space. The system uses a coordinate-based detection mechanism, providing precise recognition and pickup of books from assigned positions. To enable book handling, a forklift mechanism is implemented with the assistance of an aluminum T-extrusion frame that helps in rigidity and durability. To control motion, the system utilizes NEMA 17 stepper motors, which deliver high torque and accuracy, making them perfectly suitable for controlled movement along the X and Y axes.

The motors are driven and controlled by A4988 and L298N motor drivers, which enable smooth acceleration and deceleration. The Arduino Mega 2560 Rev3 acts as the processing unit, coordinating motor actions, managing user inputs, and interfacing peripheral devices. The Arduino CNC Shield also supports stepper motor control, making connections easier while optimizing overall system efficiency. A 12V 10A SMPS (Switched Mode Power Supply) provides a constant power supply to all electronic devices to avoid voltage fluctuation that might impact performance. The system has a 16x2 LCD with an I2C module, which offers real-time status information, such as current coordinates, book locations, and system diagnostics. User inputs are handled by push button switches, enabling manual override and input selection when required. To provide added functionality, a DC geared motor is used within the forklift mechanism to ensure controlled book lowering and lifting during book retrieval and placement. Through the use of stepper motors for positioning accuracy and the use of a geared motor for controlled lifting, a smooth and effective automated book management system is provided. Through the integration of the various hardware components

Figure 3.1: System Design Image

with embedded software programming, the system is able to provide high accuracy, reliability, and automation in the book handling process.

3.2 Programming and Control

Embedded C, especially in the context of Arduino programming, is essential in regulating the Cartesian X-Y robot's movement by handling motor control, sensor processing, and system coordination. The accuracy of the robot's movement comes from stepper or servo motors that are regulated through GPIO pins and driver modules like A4988 or DRV8825. The Arduino is supplied with position instructions, normally a computer vision setup in Python programming with OpenCV that identifies the books and comes up with coordinates. The Arduino receives these coordinates through serial transmission, enabling the Arduino to make the robot relocate to the specific position. In order to promote precision and stability, the system can be installed with limit switches for homing and encoders for feedback from the actual positions. This combination of Embedded C for low-level hardware manipulation and Python for high-level image processing provides cohesive co-operation between vision-based recognition and robotic movement, keeping the system efficacious and accurate in book retrieval processes.

3.3 Data Collection

Use a coordinate-based data collection system to accurately monitor book retrieval and placement points. By recording the X-Y coordinates of the Cartesian robot during use, the system can study usage patterns, track retrieval frequency, and maximize book organization. The data can also be used to further improve automation efficiency and inform future system performance and operational strategy improvements.

3.4 Book Delivery Mechanism

The book delivery system in LiberBot employs a Cartesian X-Y robot with a forklift-style gripper to pick up books from a C-clamped shelf system. The coordinate-based system accurately determines book positions, allowing for accurate picking. The NEMA 17 stepper motor and aluminum T-extrusion bar framework ensure stability and accuracy. After picking up a book, it is safely deposited in a drop-off location, allowing for an organized and efficient delivery process without the need for mobile robots.

3.5 CAD Design

The Fusion 360 model of the Cartesian coordinate robot and bookshelf is a highly detailed and accurate 3D representation to help envision the system's structure, motion, and component integration. The design in Fusion 360 includes several assemblies: the Cartesian X-Y-Zrobotic system, bookshelf structure, motor mounts, and electronic enclosures.

The Cartesian robot assembly is simulated with linear rails, lead screws, and stepper motor mounts, providing precise and smooth motion along the X,Y and Z axes. The X-axis rail is supported by a C-clamped support structure, enabling horizontal movement along the bookshelf. The Y-axis is a sliding carriage that translates forward and backward, while the Z-axis holds the forklift mechanism, providing vertical book retrieval.

The forklift mechanism consists of an extendable platform or gripper, which travels through a lead screw drive from a DC geared motor. The NEMA 17 stepper motors, A4988 stepper motor drivers, and L298N motor driver are fitted into specific motor housings, maintaining correct alignment and support. The Arduino Mega 2560 Rev3 and CNC Shield are contained in an independent electronics enclosure, for convenient wiring and access.

The bookshelf model in Fusion 360 is created with equally spaced compartments, allowing for accurate coordinate mapping to enable book access. The aluminum T-extrusion frame ensures strength with minimal weight. Other elements, including a 16x2 LCD with I2C module, push button switches, and a 12V 10A SMPS power supply, are incorporated into the control panel assembly. Every part in Fusion 360 is designed with joint constraints and motion simulations so that actual real-time simulation of how the robotic system moves along the path can be viewed. The design also features exploded views and detailed technical drawings for easier assembly and prototyping. The Fusion 360 model is designed to guarantee that all the mechanical, electronic, and structural parts fit exactly together, which results in a highly efficient and well-optimized book retrieval system.

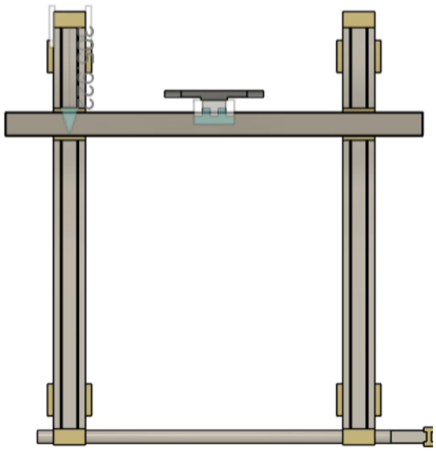


Figure 3.2: Cartesian coordinate robot

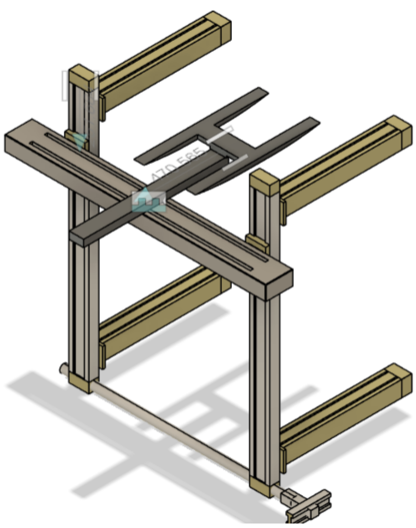


Figure 3.3: Cartesian coordinate robot

3.6 Hardware Components

3.6.1 A4988 Stepper Motor Driver

The A4988 stepper motor driver controls the stepper motors with precision, supporting full-step to 1/16th microstepping for smooth motion. The STEP pin triggers movement, the DIR pin sets direction, and the ENABLE pin powers the motor on or off.

Current regulation via the VREF pin prevents overheating, while built-in overcurrent and thermal protection ensure safe operation. It operates on 12V to 35V, delivering up to 2A per coil with proper cooling. Adjustable current limiting allows customization based on motor needs.

3.7 Nema 17 Stepper Motor

NEMA 17 stepper motors (1.7 x 1.7 inches) play a crucial role in LiberBot's precise motion control, ensuring accurate book retrieval and reshelving. With a 1.8-degree step angle (200 steps/rev), they provide fine positioning without the need for feedback. Operating on a 24V DC supply, they are controlled by A4988 drivers, supporting microstepping for smoother motion and reduced vibrations. With a torque of 45–65 oz-in, these motors efficiently drive the Cartesian X-Y system and forklift mechanism while maintaining stability and energy efficiency.

3.7.1 L298N Motor Driver

The L298N motor driver controls LiberBot's DC motors using a dual H-Bridge circuit, allowing bidirectional movement. It operates at 5V–35V with a current capacity of up to 2A per motor. Features include thermal shutdown protection, a built-in 5V regulator, and PWM-based speed control for precise motion. It interfaces easily with Arduino for efficient operation in book retrieval.

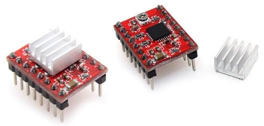


Figure 3.4: A4988 Stepper Motor Driver

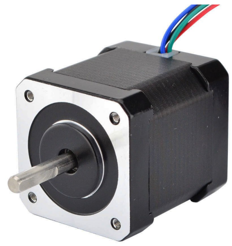


Figure 3.5: Nema 17 Stepper Motor

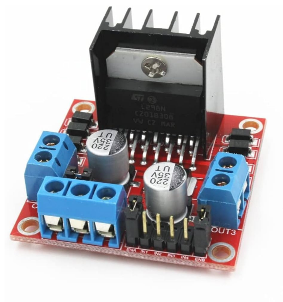


Figure 3.6: L298N Motor

3.7.2 Arduino Mega 2560 Rev3

The Arduino Mega 2560 Rev3 is the core controller of LiberBot, managing motion, sensors, and automation processes. It runs on the ATmega2560 microcontroller with a 16 MHz clock, 256 KB flash memory, 8 KB SRAM, and 4 KB EEPROM. With 54 digital I/O pins (15 PWM) and 16 analog inputs, it enables precise motor and sensor control. Four UART serial ports and I2C/SPI communication allow seamless integration with modules like motor drivers and displays. Powered via USB or an external adapter (7-12V), it ensures stable operation. Its compatibility with the Arduino IDE simplifies programming, making it efficient for LiberBot's automated book retrieval system. With its robust capabilities, wide range of I/O support, and simplicity of use, the Arduino Mega 2560 Rev3 is a great pick for designing large-scale or high-performance embedded systems. Its reliability and versatility make it an ideal choice for sophisticated automation and control applications.

3.7.3 12V 10A SMPS

A 12V 10A SMPS (Switched-Mode Power Supply) is a highly efficient power conversion unit that provides a stable 12V DC output with a maximum current capacity of 10A, delivering up to 120W of power. It is widely used in robotics, automation, CNC machines, 3D printers, motor drivers, LED lighting, and other applications requiring reliable and regulated power.

SMPS works by rapidly switching the input voltage through high-frequency circuits, minimizing power loss and reducing heat dissipation compared to traditional linear power supplies. This switching mechanism improves efficiency, often exceeding 85

It supports a broad AC input voltage range (typically 100V to 240V AC), making it compatible with global power standards. Built-in protections, including overvoltage, overcurrent, short-circuit, and thermal protection, ensure safe operation and prevent damage to connected components. One of the major benefits of an SMPS is its small size, light

Figure 3.7: 12V 10A SMPS

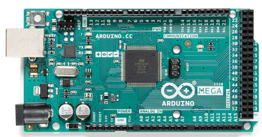


Figure 3.8: Arduino Mega

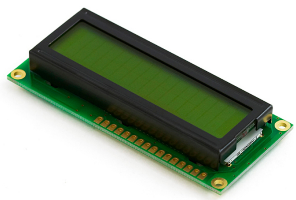


Figure 3.9: 16×2 LCD

weight, and energy efficiency, usually more than 80 percentage efficiency compared to large linear power supplies. It also features intrinsic protection aspects like overvoltage protection, short-circuit protection, overcurrent protection, and thermal shutdown, making it safe and reliable to operate.

3.7.4 16x2 LCD

A 16x2 LCD (Liquid Crystal Display) is a popular alphanumeric display module that can display two lines of 16 characters each. It is widely employed in embedded systems, microcontroller projects, industrial applications, and consumer electronics to display real-time data like sensor readings, system status, and user interfaces. The screen uses an onboard HD44780 controller, which makes it easy to work with microcontrollers such as Arduino, PIC, AVR, and ESP32 using either a 4-bit or 8-bit parallel data interface.

The 16x2 LCD is usually powered by 5V power and has a contrast adjustment pin (V0) used to adjust the visibility of the display. It also comes with a backlight (LED-based) to enhance readability in dim lighting.

It can be driven by communication with the 16x2 LCD through an I2C adapter module, allowing the number of control pins needed to be lowered from 6-8 to merely two (SDA and SCL).

3.7.5 LCD I2C Module

An LCD I2C module is an interface board that makes it easy to connect an 16x2 LCD (or other HD44780 displays) to a microcontroller over the I2C (Inter-Integrated Circuit) protocol. It greatly lowers the number of GPIO pins needed, enabling communication with the LCD via only two pins: SDA (Serial Data) and SCL (Serial Clock), rather than the conventional 6-8 parallel data connections. This makes it particular for projects on Arduino, ESP8266, ESP32, or STM32 microcontrollers. The LCD I2C module is constructed using the PCF8574 I/O expander chip, which translates I2C signals into parallel signals for the LCD. It features an adjustable potentiometer for contrast adjustment, a backlight control jumper, and pull-up resistors to stabilize I2C communication. The module usually runs at 5V, which is the same power requirement of most 16x2 and 20x4 LCD displays.

3.7.6 Push Button Switch

A push button switch is an electrical device that operates circuits by breaking and making connections upon being pressed. It is a momentary switch, meaning it only stays active while being pressed and returns to its original state when released. Push buttons are of different types, such as normally open (NO), which closes the circuit upon being pressed, and normally closed (NC), which opens the circuit upon being pressed. There are also switches with latching mechanisms, whereby they remain in the pressed position until pressed once more. Push button switches find extensive applications in electronics, industrial automation, home appliances, and embedded systems for purposes such as power control, device resetting, alarm activation, and user input in microcontroller projects.

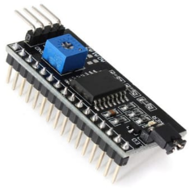


Figure 3.10: LCD 12C Module

Figure 3.11: Push Button

Figure 3.12: DC Motor

3.7.7 DC Geared Motor

A DC geared motor is an essential component of LiberBot, providing controlled rotational motion with high torque for precise movement. It consists of a DC motor coupled with a gearbox, which reduces speed while increasing torque, ensuring smooth and efficient operation. This motor is crucial for driving mechanical systems such as the forklift mechanism, enabling accurate book retrieval and reshelving. The gear reduction system enhances stability and load-handling capability, minimizing power consumption while maintaining efficiency. Its compact design, durability, and precise speed control make it ideal for automation in LiberBot, ensuring seamless and reliable performance in library environments.

3.8 Robotic Frame Components

Robotic components are crucial for LiberBot, providing a precise and stable framework for its Cartesian X-Y robotic system. The 2040 aluminum extrusion bar serves as the backbone, offering strength, rigidity, and easy assembly with its T-slot design. 2040 corner brackets reinforce the frame for stability. Motion transmission is achieved using a GT2 timing belt (10mm width) with minimal backlash, meshing seamlessly with driver and idler pulleys. V-wheels enable smooth, low-friction linear motion along the extrusions. NEMA 17 stepper motors, secured by motor mounts, drive the system with precision while minimizing vibrations. T-nuts and M5 screws provide secure and adjustable fastening for various components. Aluminum and eccentric spacers maintain alignment, allowing fine-tuning of wheel-to-rail contact pressure. CNC-machined gantry plates mount moving parts, ensuring even load distribution. These components work together to enhance LiberBot's accuracy, stability, and efficiency in book retrieval and reshelving operations.

(a) Motor mounts (b) 2040 aluminum extrusion bar (c) Gantry Plates

(d) Pre-insertion T-nuts (e) 2040 corner brackets (f) V-wheels

(g) GT2 timing belt (h) Driver pulleys (i) Idler pulleys

Figure 3.13: Robotic Frame Components

3.9 Circuit Diagram

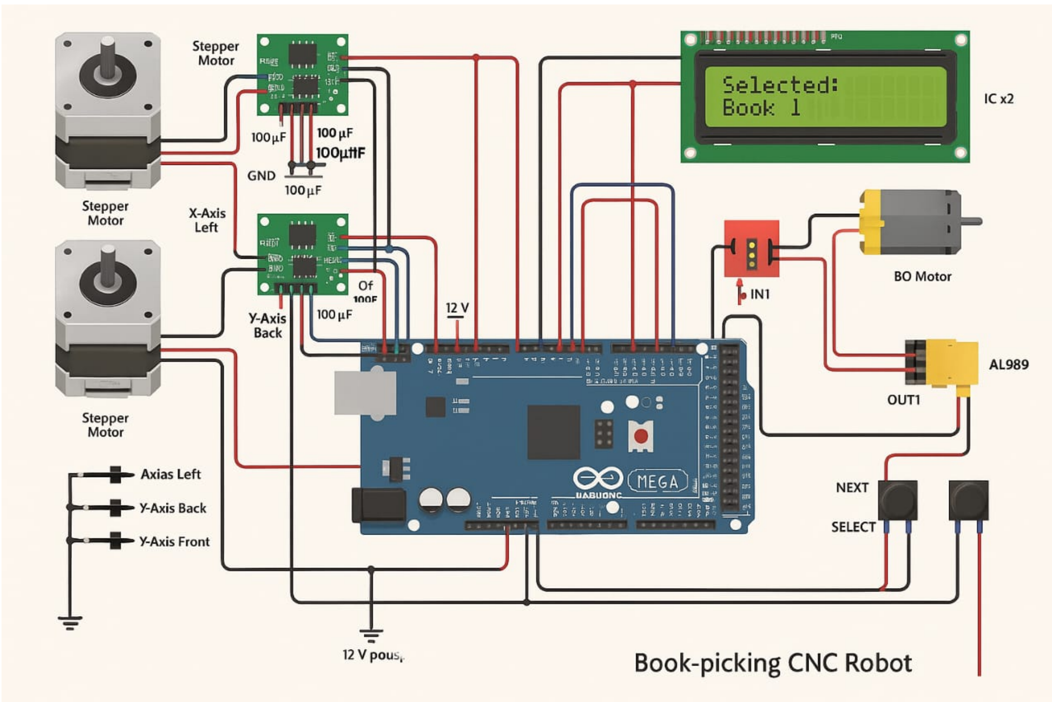


Figure 3.14: Circuit Diagram

3.10 Working

The LiberBot system efficiently retrieves and reshelves books using a forklift mechanism for secure handling and navigation. Upon receiving a request, sensors scan the shelves to locate the book. The NEMA 17 stepper motors, secured by motor mounts, drive the Cartesian X-Y robotic system, ensuring precise movement along the 2040 aluminum extrusion bar framework.

The GT2 timing belt (10mm width), along with driver and idler pulleys, enables smooth and accurate motion, while V-wheels ensure low-friction linear travel. Once positioned, the forklift mechanism, mounted on CNC-machined gantry plates, lifts and holds the book securely for transportation. T-nuts and M5 screws provide structural stability, while aluminum and eccentric spacers maintain precise alignment. The system then navigates efficiently, avoiding obstacles, and upon reaching the delivery point, the quick-release mechanism gently places the book, ensuring a seamless and reliable automated library experience.

Figure 3.15: Working Model

Figure 3.16: Working Model

CHAPTER 4

EMBEDDED C ARDUINO PROGRAM FOR CARTESIAN COORDINATE ROBOT MOVEMENT

sketch_mar31c §

```
// === Book Picking CNC Robot Code ===

#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include <AccelStepper.h>

// LCD Setup
LiquidCrystal_I2C lcd(0x27, 16, 2);

// Stepper Motor Pins
#define X_STEP_PIN 2
#define X_DIR_PIN 3
#define Z_STEP_PIN 4
#define Z_DIR_PIN 5

// Stepper Enable Pins
#define X_ENABLE_PIN 8
#define Z_ENABLE_PIN 9

// Define Stepper Motors
AccelStepper stepperX(AccelStepper::DRIVER, X_STEP_PIN, X_DIR_PIN);
AccelStepper stepperZ(AccelStepper::DRIVER, Z_STEP_PIN, Z_DIR_PIN);

// Y-Axis BO Motor via L298N
#define Y_FORWARD_PIN 6   // IN1
```

Figure 4.1: Program

```
// Limit Switches
#define X_LIMIT 16
#define Y_BACK_LIMIT 15
#define Y_FRONT_LIMIT 14
#define Z_LIMIT 17

// Buttons
#define NEXT_BUTTON 12
#define SELECT_BUTTON 13

// Book and Center Positions: {X, Z}
const int numPositions = 4;
const char *positionTitles[numPositions] = {"Book 1", "Book 2", "Book 3", "Center"};
int positionValues[numPositions][2] = {
    {600, 100},  // Book 1: X, Z initial lift
    {850, 100},  // Book 2
    {1100, 100}, // Book 3
    {700, 150}   // Center position: X, Z
};

int selectedBook = 0;

void setup() {
  Serial.begin(115200);
```

Figure 4.2: Program

```
lcd.init();
lcd.backlight();
lcd.setCursor(0, 0);
lcd.print("Select Book:");

pinMode(X_ENABLE_PIN, OUTPUT);
pinMode(Z_ENABLE_PIN, OUTPUT);
digitalWrite(X_ENABLE_PIN, LOW);
digitalWrite(Z_ENABLE_PIN, LOW);

stepperX.setMaxSpeed(1000);
stepperX.setAcceleration(500);
stepperZ.setMaxSpeed(1000);
stepperZ.setAcceleration(500);

pinMode(Y_FORWARD_PIN, OUTPUT);
pinMode(Y_BACKWARD_PIN, OUTPUT);

pinMode(X_LIMIT, INPUT_PULLUP);
pinMode(Y_BACK_LIMIT, INPUT_PULLUP);
pinMode(Y_FRONT_LIMIT, INPUT_PULLUP);
pinMode(Z_LIMIT, INPUT_PULLUP);

pinMode(SELECT_BUTTON, INPUT_PULLUP);
pinMode(NEXT_BUTTON, INPUT_PULLUP);
```

Figure 4.3: Program

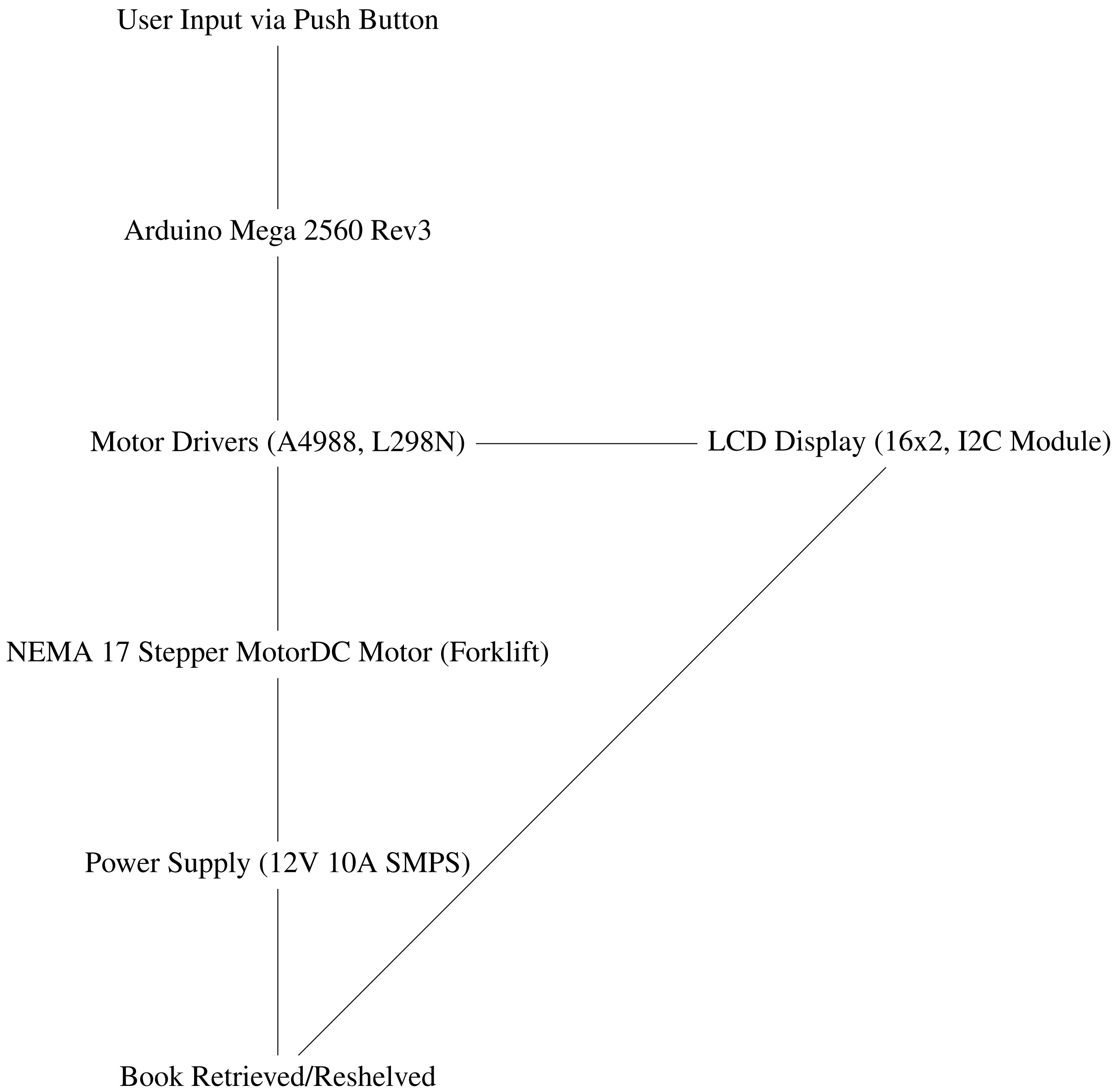
```
void loop() {
  if (digitalRead(NEXT_BUTTON) == LOW) {
    selectedBook = (selectedBook + 1) % (numPositions - 1);
    updateLCD();
    delay(300);
  }
  if (digitalRead(SELECT_BUTTON) == LOW) {
    pickBook(selectedBook);
    delay(500);
  }
}

void updateLCD() {
  lcd.clear();
  lcd.setCursor(0, 0);
  lcd.print("Selected:");
  lcd.setCursor(0, 1);
  lcd.print(positionTitles[selectedBook]);
}

void homeAxes() {
  Serial.println("Starting Homing Sequence...");

  // Ensure Y-back switch is not already pressed
  while (digitalRead(Y_BACK_LIMIT) == LOW) {
```

Figure 4.4: Program

```
void homeAxes() {
  Serial.println("Starting Homing Sequence...");

  // Ensure Y-back switch is not already pressed
  while (digitalRead(Y_BACK_LIMIT) == LOW) {
    Serial.println("Y-back limit is LOW before movement. Waiting...");
    delay(500);
  }

  // Step 1: Move Y back
  Serial.println("Homing Y-axis...");
  while (digitalRead(Y_BACK_LIMIT) == HIGH) {
    digitalWrite(Y_FORWARD_PIN, LOW);
    digitalWrite(Y_BACKWARD_PIN, HIGH);
  }
  digitalWrite(Y_BACKWARD_PIN, LOW);
  Serial.println("Y-axis homed.");
  delay(300);

  // Step 2: Move X to left (home)
  Serial.println("Homing X-axis...");
  while (digitalRead(X_LIMIT) == HIGH) {
    stepperX.setSpeed(-500);
    stepperX.runSpeed();
  }
```

Figure 4.5: Program

LiberBot Hardware Flowchart



CHAPTER 5

RESULTS AND DISCUSSIONS

LiberBot was tested for book retrieval and reshelving efficiency. The system accurately navigated the Cartesian X-Y coordinates, identifying book locations within shelf compartments. NEMA 17 stepper motors, controlled via A4988 drivers, ensured precise movement, while the GT2 timing belt and V-wheel mechanism enabled smooth, low-friction motion.

The forklift mechanism extended and retracted using a lead screw drive powered by a DC geared motor. A push-button interface and 16x2 LCD module allowed easy book selection, while limit switches prevented overtravel, ensuring reliable operation. A 12V 10A SMPS provided stable power, and the Arduino Mega 2560 with a CNC Shield efficiently handled motor control and coordinate mapping.

Challenges included initial misalignment of shelf compartments, requiring recalibration. Vibrations from rapid movements were reduced by adjusting motor acceleration and wheel-to-rail contact pressure. Testing different book sizes led to minor modifications in the forklift's gripping mechanism for improved stability. LiberBot demonstrated improved book retrieval efficiency over manual methods, reducing retrieval time and enhancing accuracy. Future upgrades may include sensor-based book identification, wireless control, and a refined user interface. The results confirm the system's functionality, with scope for further optimization to enhance library automation.

Figure 5.1: LiberBot

CHAPTER 6

CONCLUSION

Phase 1 of the Library Automation Project successfully laid the foundation for an efficient book retrieval system. The project introduced a Cartesian X-Y robot with a forklift-style gripper and a coordinate-based mechanism to enhance book handling and organization.

Designed to reduce retrieval time and improve accuracy, the system incorporates NEMA 17 stepper motors with DRV8825 drivers, an aluminum T-slot extrusion frame for stability, and a C-clamping-based shelf structure for book storage. Sensor-based identification assists in locating books efficiently.

Key robotic components ensure precision and stability. The 2040 aluminum extrusion bar provides a strong framework with easy T-slot assembly, reinforced by 2040 corner brackets. A GT2 timing belt (10mm width) enables smooth motion with minimal backlash, supported by driver and idler pulleys. V-wheels allow low-friction movement, while motor mounts secure the NEMA 17 stepper motors, minimizing vibrations. T-nuts, M5 screws, aluminum and eccentric spacers ensure proper alignment, and CNC-machined gantry plates distribute loads evenly. Limit switches and linear rails enhance motion accuracy.

The system operates using an Arduino Mega 2560 Rev3, CNC Shield, and Python-C programming for motion control. A push-button mechanism enables user interaction. With this phase completed, the project moves toward integration, testing, and refinement, bringing it closer to an advanced and efficient library automation system.

CHAPTER 7

FUTURE SCOPE

Future work for LiberBot can focus on several key advancements to enhance its functionality and efficiency. Implementing advanced computer vision can allow the system to recognize books by their spines and titles, reducing dependency on predefined coordinates. AI-driven book sorting can be introduced to enable automatic classification and organization based on user demand and category relevance. IoT integration can facilitate remote monitoring and real-time book tracking, allowing librarians to manage requests and monitor robot performance from anywhere. Multi-robot coordination can be developed to enable multiple LiberBots to work collaboratively in large libraries, improving operational efficiency. Self-calibration and predictive maintenance can be added to detect mechanical issues before failures occur, ensuring smooth operation. Enhanced gripping mechanisms can be designed to accommodate books of varying sizes and weights without damage. Cloud-based data analysis can be integrated to study borrowing patterns and optimize book placement for better accessibility. Voice or chatbot-assisted interaction can be introduced to allow users to request books through natural language commands. These advancements will further improve LiberBot's automation capabilities, making it a more intelligent and adaptive library assistant.

CHAPTER 8

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