DEVELOPMENT OF SMART LIBRARY ASSISTANT ROBOT

18MHP109L - MAJOR PROJECT REPORT

Submitted by

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BONAFIDE CERTIFICATE

Certified that this project report titled **Development of Smart Library Assistant Robot** is the bonafide work of **Rituraj Ramesh Shinde (RA2011038010020), Mohamed Hisham (RA2011038010022)** and **Sushant Shirish Sapkal (RA2011038010024)**, who carried out the project work under my supervision. Certified further, that to the best of my knowledge the work reported here does not form any other project report or dissertation on the basis of which a degree or award was conferred on an earlier occasion on this or any other candidate.

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ABBREVIATIONS

ROS - Robot Operating System

RFID - Radio-Frequency Identification.

LIDAR- light detection and ranging

SLAM - Simultaneous localization and mapping

M1 - Motor 1

M2 - Motor 2

M3 - Motor 3

M4 - Motor 4

RPWM - Random pulse width modulation

LPWM - Logical Pulse with Modulation

R_EN - Forward Drive Enable input

L_EN - Reverse Drive enable Input

R_IS - Forward Drive, Side Current alarm Output

L_IS - Reverse Drive , Side Current Alarm Output

Vcc - +5V Power Supply

Gnd - Ground Power Supply

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ABSTRACT

This project offers an integrated approach meant to transform conventional book retrieval procedures in response to the changing library services landscape and technology advancements. Modern RFID technology and sophisticated obstacle avoidance techniques are used in the proposed Smart Library Robo Assistant to maximize user satisfaction and operational effectiveness in library settings.

The use of RFID tags inserted in every library book is essential to the system's operation. In response to a user's request for a particular book, the Smart Robo Assistant uses this information to walk the library's aisles on its own, using RFID scanners to quickly find the desired item. By means of an efficient combination of artificial intelligence and data supplied by the user, the system guarantees prompt and precise book retrieval, hence curbing waiting times and augmenting user contentment.

Modern obstacle avoidance technology is also included in the Smart Robo Assistant to help with the inherent difficulties of traversing busy and dynamic library areas. Using a variety of sensors such as infrared and laser sensors the robot continuously scans its environment to identify and avoid obstacles. By reducing the chance of collisions, this proactive strategy not only protects the integrity of library resources but also guarantees the safety of library users. Additionally, the modular design of the system emphasizes its versatility and scalability by facilitating future extension and smooth connection with current library infrastructures. Libraries may enhance their service offerings and better serve the changing requirements of their users while streamlining operational procedures and allocating resources by utilizing automation and robotic. In conclusion, the Smart Library Robo Assistant is a revolutionary step forward for library services, utilizing cutting-edge robotics and RFID technology to provide unmatched precision, efficiency, and security in book retrieval operations. Libraries may improve accessibility, simplify operations, and reinforce their position as active centers of knowledge dissemination in the digital age by embracing innovation.

CHAPTER 1

INTRODUCTION

1.1 BRIEFING

In this chapter we will be discussing the creation of a Smart Library Assistant Robot signals the beginning of a new era of effectiveness and ease in the world of contemporary libraries, where innovation and technology mingle with established knowledge warehouses. This project aims to revolutionize the way books are accessed and retrieved in library environments by developing a state-of-the-art solution that seamlessly incorporates robotics, RFID technology, and autonomous navigation.

The Smart Library Assistant Robot's primary function is to move from a predetermined home position to bookcases on its own. To achieve this, it combines a complex system of Raspberry Pi for strong coordination and control with Arduino-controlled motors. The Arduino microcontroller coordinates motor operations, allowing the robot to move around the library with accuracy and efficiency.

The Smart Library Assistant Robot's incorporation of RFID technology is essential to its operation. The robot can detect and find requested books among the large assortment of books in the library thanks to RFID tags that are thoughtfully placed on each book. Through the scanning of RFID tags, the robot is able to quickly and accurately collect books with unmatched speed and accuracy, removing the need for human intervention and optimizing the retrieval process.

The core of the project's software foundation is the ROS, which enables autonomy and intelligent navigation. By utilizing ROS, the robot is able to precisely and nimbly move through the library's environment and plan its own route to the assigned bookcases. In addition, the implementation of LiDAR sensors enables instantaneous mapping and obstacle avoidance, guaranteeing secure navigation across the library area.

The Smart Library Assistant Robot stands out due to its user-friendly interface, which makes it simple for users to engage with the system. Users can transmit their book retrieval requests to the robot using voice commands, text input, or the book's unique RFID ID. The robot then goes on its mission to get the requested book.

In conclusion, the creation of a smart library assistant robot is an example of how traditional library services and cutting-edge technology have come together. This project intends to improve the productivity, accessibility, and overall experience of both library personnel and visitors by seamlessly combining robots, RFID technology, autonomous navigation, and user-friendly interfaces. It also paves the way for a smarter and more connected library environment.

1.2 BACKGROUND AND MOTIVATION

1.2.1 Background

The creation of a Smart Library Assistant Robot represents a significant development in library technology that will transform the way books are retrieved. The robot uses a Raspberry Pi for communication and an Arduino for motor control to move itself from its starting point to the library's bookshelves. By utilizing RFID technology, the robot can precisely identify and retrieve requested objects by scanning book tags. The ROS facilitates the robot's autonomy, while LiDAR sensors guarantee safe navigation and effective path planning. Customers can request books by name or RFID ID thanks to the user-friendly interface, which improves accessibility and convenience. To put it briefly, the project combines robotics, RFID technology, self-navigating capabilities, and intuitive user interfaces to build a more intelligent and effective library ecosystem that benefits both users and staff.

1.2.2 Motivation

The goal of developing a smart library assistant robot is to solve the problems and inefficiencies that come with using standard library systems. The efficiency of library operations is generally hampered by the time-consuming and error-prone nature of manual book retrieval procedures. Our goal is to improve user experience by introducing a robotic system that can autonomously navigate to bookshelves, scan RFID tags, and collect requested books. A scalable and affordable platform for robot development is offered by the combination of Raspberry Pi for communication and Arduino for motor control. Using LiDAR for path planning and ROS for autonomy allows for safe and effective navigation in the library setting. We placed ease and accessibility first by allowing users to input book names or RFID IDs for retrieval. The project's ultimate objective is to modernize library services by increasing their effectiveness, usability, and ability to adjust to the digital era. We see a future where libraries can better serve their patrons' needs while maximizing resource utilization and raising overall operational efficiency by utilizing robotics and cutting-edge technologies.

1.3 CHALLENGES IN THE EXISTING SYSTEM AND METHOD

Numerous issues that could impair the effectiveness and user experience of the current book stacking and dispensary system in libraries include: -

Manual Procedures: The dispensary and book stacking in traditional libraries mainly rely on manual procedures. The time-consuming and error-prone nature of this manual labor might result in inefficient management of library resources.

Space Restrictions: Libraries frequently lack adequate space for storing books, which results in crowded shelves and makes it challenging to find specific books. Customers may become irate as a result, and library employees may find it difficult to keep things in order.

Lack of Accessibility: Those with mobility limitations may find it difficult to reach books on upper shelves in libraries with multi-level shelving or restricted accessibility. The library may not be able to adequately serve every person of the community because of this lack of accessibility.

Inventory management: Maintaining an accurate manual inventory of a library can be a difficult undertaking, particularly in larger institutions with substantial holdings. In the absence of effective inventory management systems, libraries can find it difficult to keep precise records of the availability and placement of books.

Staff Workload: Manually replenishing shelves and helping customers retrieve books are frequent responsibilities of library staff. This workload can be excessive, especially during busy times, which could cause delays in serving customers and more stress for the employees.

Security Issues: Libraries need to handle issues with theft and misplacing of books. Libraries may suffer losses in their collection in the absence of adequate security and monitoring procedures, which could affect the availability of books for users.

Innovative approaches that use technology to boost accessibility, automate procedures, and increase productivity in library book stacking and dispensary operations are needed to address these issues. By putting in place technologies like computerized inventory management, automated retrieval systems, and RFID technology, libraries may overcome these obstacles and offer improved services to both staff and customers.

1.4 APPLICATION

The Smart Library Assistant Robot can be applied in a variety of locations where self-service book retrieval and navigation are necessary, not just traditional libraries. The following are a few possible uses:

Academic Libraries: The Smart Library Assistant Robot can help faculty and students find books and research materials at academic libraries. It can independently browse the library shelves, assisting users in quickly finding certain volumes.

Retail Environments: The Smart Library Assistant Robot can be used for inventory management and retrieval in retail establishments with a vast product inventory, such as department shops or bookstores. It can improve customer service and operational efficiency by navigating retail aisles, scanning product barcodes, and retrieving things for customers.

Educational Institutions: To help teachers and students access instructional materials, schools, colleges, and universities can install the Smart Library Assistant Robot in their libraries or resource centers. It can independently retrieve instructional aids, reference books, and textbooks to enhance on-campus learning and research endeavors.

Warehouse Management: The Smart Library Assistant Robot can be used by warehouses and distribution centers to handle inventory and fulfill orders. It can discover certain products, find its way through warehouse aisles on its own, and retrieve items for delivery or restocking, all while optimizing warehouse operations.

Healthcare institutions: The Smart Library Assistant Robot can be used by hospitals and other healthcare institutions to help medical personnel get patient records, equipment, and supplies. It can improve the efficiency of healthcare delivery by navigating hospital hallways, reading RFID tags on medical supplies, and delivering them to the right places.

Office Environments: For document retrieval and organization, offices with sizable document archives or resource libraries can use the Smart Library Assistant Robot. By finding particular documents or files on its own, finding its way across offices, and delivering them to staff members, it can increase efficiency and productivity.

All things considered, the Smart Library Assistant Robot is a flexible way to enhance both user experience and operational efficiency since it can be used in a wide range of settings and sectors where autonomous item retrieval and navigation are required.

1.5 METHODOLOGY

Requirements Analysis -

Determine the precise needs and goals of the Smart Library Assistant Robot project, considering features like RFID scanning, user interface design, autonomous navigation, and integration with Lidar, Arduino, Raspberry Pi, and ROS.

Hardware Configuration-

- Building the chassis for the mobile robot
- Set up the hardware, such as the Raspberry Pi for connectivity, the Arduino for motor control, and the Lidar sensor for route planning.
- Connection between the Raspberry Pi and Arduino to ensure a smooth integration.

Software Engineering-

- Provide ROS-based software algorithms with path planning and obstacle avoidance features for autonomous navigation.
- Incorporate RFID scanning features so that the robot can recognise and find books using their RFID tags.
- Create a user-friendly interface using a Raspberry Pi for user communication for entering book titles or RFID IDs.

Testing and Integration:

- Combine software and hardware elements to produce a working prototype of a smart library assistant robot.
- To guarantee the dependability, precision, and effectiveness of RFID scanning, autonomous navigation, and user interaction features, do thorough testing.
- Conduct validation testing in actual library settings to evaluate the robot's functionality and performance.

Refinement by Iteration:

- Get opinions on the functionality and performance of the prototype from users, librarians, and other relevant parties.
- Iteratively modify the hardware and software components by taking into account user feedback to improve functionality and fix any flaws found.
- Verify and test again to make sure the improved prototype satisfies the project's goals and specifications.

Documentation and Implementation:

- Record the hardware requirements, software architecture, testing results, and algorithms used during the design, development, and testing phases.
- To make the deployment and adoption of the Smart Library Assistant Robot in library contexts easier, prepare user manuals and training materials.
- Install the Smart Library Assistant Robot's final version in libraries, offering staff and patrons the necessary assistance and training.

By using this technique, we can be sure that the Smart Library Assistant Robot will be developed, tested, and deployed successfully, fulfilling our project goals of improving user experience and library operations through self-navigating and autonomous book retrieval.

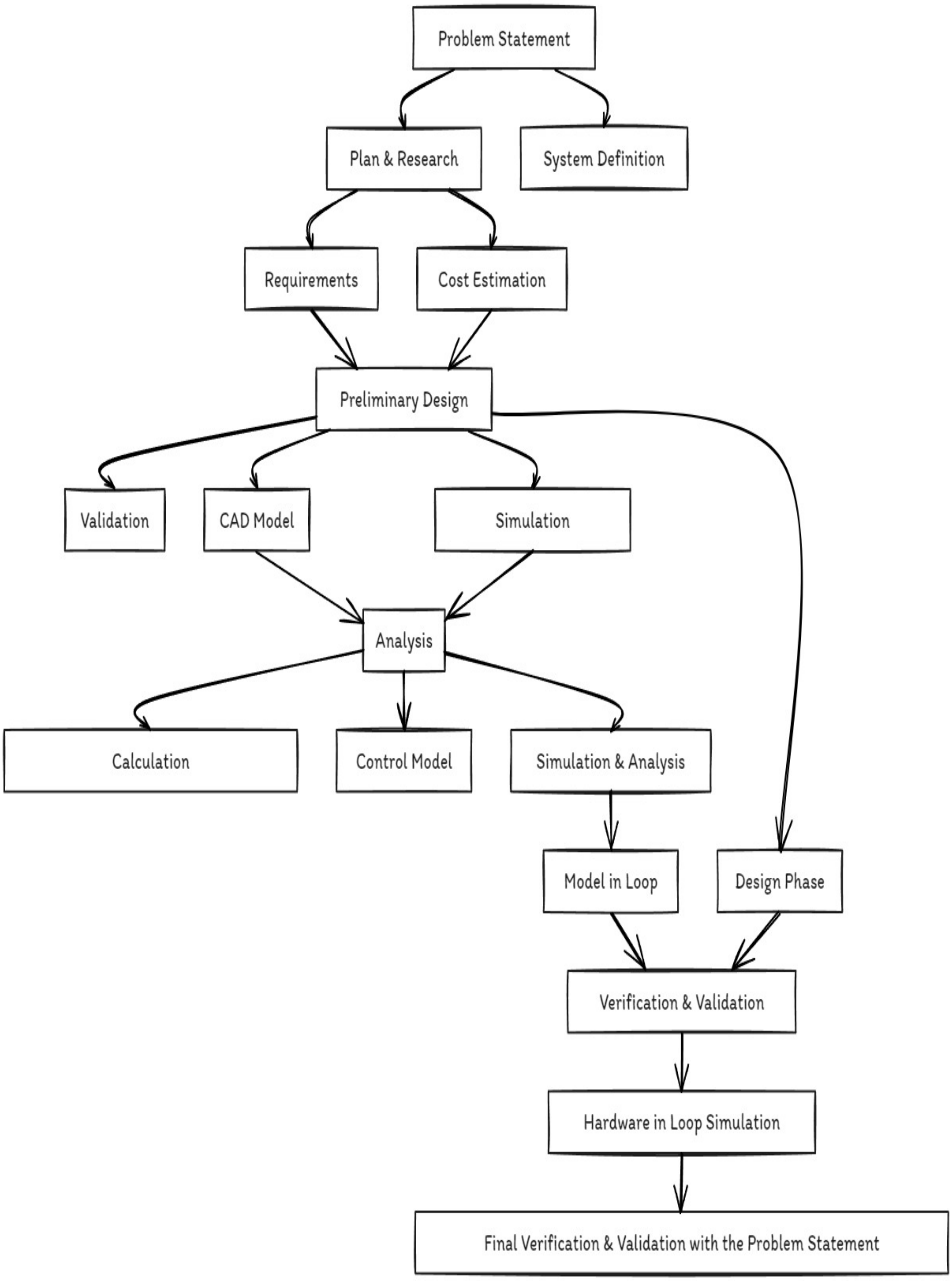

Figure 1.1 Methodology of Proposal Model

1.6 ORGANIZATION OF THE REPORT

The report is planned as follows.

CHAPTER 1- Introduction and Background of the proposed Project also the motivation behind it also the Methodology for making the project is described in detailed

CHAPTER 2 - This chapter elaborates about the Literature Survey in the field of the existing mobile manipulator for book stacking and retrieval system, which include different type of method for book stacking and retrieval process

CHAPTER 3 - The chapter Elaborate System Architecture also showcase the mechanical, electrical, software and control system design . The proposed mechanical design with its unique feature, all electronics and control system is designed in this chapter.

CHAPTER 4 - The basic idea of how ROS manages pathfinding and spatial awareness, two tasks essential to autonomous robot navigation is covered in this chapter. It highlights how mapping which involves building a model of the environment and navigation which involves making plans and following a path inside it integrate to provide the fundamental building blocks of robotic autonomy.

CHAPTER 5 - Talk about the project's future development, the summary of its achievements and limitations, and its conclusion.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter we will discuss the various research papers referred to understand various methodology, working, and models used in the existing library automation process .

2.2 RELATED WORKS

G A, Archan Y, Bindu B, Sumalatha N , Prof. Suma V Shetty Vol.8 Issue 06,June-2019 presented a paper titled "**Library Assistant Robot** "This paper tells us about the design and implementation of prototype robot identifying books on shelves. Also to develop an automated service robotic assistant using Rfid ,IR sensor, DC motor(1)Apoorva

M Babu Prasad Vol 118 No.18 2018 Presented a paper title "**Smart Library Robo Assistant System**" This Paper tell us about the Result of finding the book in the library automatically using RFID Technology .(3)

Tushit Gupta, Rohit Tripathi, Manoj K.Shukla, Shailendra Mishra. IJET 1(2):1105-1109(2020) presented a paper **"Design and development of IOT Based Smart Library using Line Follower Robot "**the objective of this paper is to automate the existing system in the library which include search, detect, pick and place the book in the shelve by following fixed line path.

Jukie behan , Derek T.O'Keeffe Intel Serv Robotics(2008) 1:73-89 presented a paper **"The Development of an autonomous service robot .Implementation of 'LUCAS'-The library assistant Robot "**The localization mechanisms employed by the robotic development are fully explained in terms of their basic image processing methods fused with sonar and odometry data.which an extended Kalman filter (EKF) is used to validate.

Akshay kumar ,Anurag Mishra ,Pooja Makula ,Krit karan and V.K Mittal 2015 IEEE Region 10 Symposium presents a paper " **Smart Robotic Assistant "** tell us about prototype of smart robotic assistant which voice commands are communicated to an online server.

Arjun K Jayaprakash, Aswani C R, Deepthi U, Ganesh S IJERTV6IS010092 Volume 06, Issue 01 January 2017 IJERT presents a paper **" Library Assistant Robot "** tell us Using line-following sensors to guide its route, a library robot uses keypad input to go from its home base to acquire books. When sensors determine that the book is in the right place, it retrieves it from the assigned shelf and moves back to its starting position. Following delivery, the robot readies itself for the subsequent duty by displaying a success message on the LCD.

CHAPTER 3

SYSTEM ARCHITECTURE

3.1 INTRODUCTION

Mechanical, electrical, and control systems make up the three primary categories of system design for a mobile manipulator for book stacking and dispensary systems that can locate books using RFID scanners and carry out user directions.

3.2 MECHANICAL DESIGN

Many important factors are crucial to the mechanical design of the Smart Library Assistant Robot. First and foremost, the chassis acts as the framework for the robot. It must strike an equilibrium between strength and lightness to support the various parts of the robot and maintain smooth motion. Another important factor is mobility, which requires careful consideration when choosing wheels, motors, and suspension systems to enable easy navigation around library environments.

The robot's ability to function depends critically on the sensor installation. For reliable navigation and mapping, the Lidar sensor needs to be positioned as best it can, and the RFID scanner needs a clear line of sight to scan book tags. To ensure effective retrieval, the gripper mechanism must also be built to safely handle books of different sizes and shapes.

The robot's mechanical design has safety features such as emergency stop mechanisms and collision avoidance systems to safeguard users and the robot itself. Another important feature is modularity, which makes maintenance, assembly, and future upgrades simple. In addition, aesthetics are taken into account to provide a visually pleasing robot that enhances the library setting and encourages interaction with users.

Iterative testing and prototyping are essential throughout the design process. By constructing prototypes, mechanical components may be tested in simulated situations and the results can be used to inform iterative design changes. The Smart Library Assistant Robot's mechanical design guarantees the best possible functionality, safety, and user experience in library environments by abiding by these criteria

3.2.1 Cad Model

The mobile robot's CAD model features a chassis made of aluminum hollow tubes, which were selected for their strength and lightweight. L-clamps and self-screws are used to unite these well-planned channels, creating a sturdy and safe foundation for the robot's parts. By optimizing the robot's weight distribution and preserving structural integrity, aluminum hollow tubes enhance mobility.

The presence of a manipulator arm connected to the robot's side is a significant characteristic of the CAD model. The lead screw components used in the construction of this manipulator arm are renowned for their accuracy and dependability in applications requiring controlled movement. The manipulator arm's gripper can move smoothly and precisely vertically thanks to the lead screw mechanism, which makes it possible to retrieve books from shelves of different heights with efficiency.

The gripper mechanism is engineered to provide dependable handling during the retrieval process by securely grasping books of varying sizes and shapes. The gripper mechanism and lead screw manipulator arm work together to improve the robot's functionality by allowing it to find bookshelves on its own, precisely select books, and put them back where they belong.

All things considered, the CAD model shows a carefully constructed mobile robot with an accurate manipulator arm, robust chassis, and effective gripper mechanism, which makes it the perfect choice for independent book retrieval in library environments.

ISOMETRIC VIEW

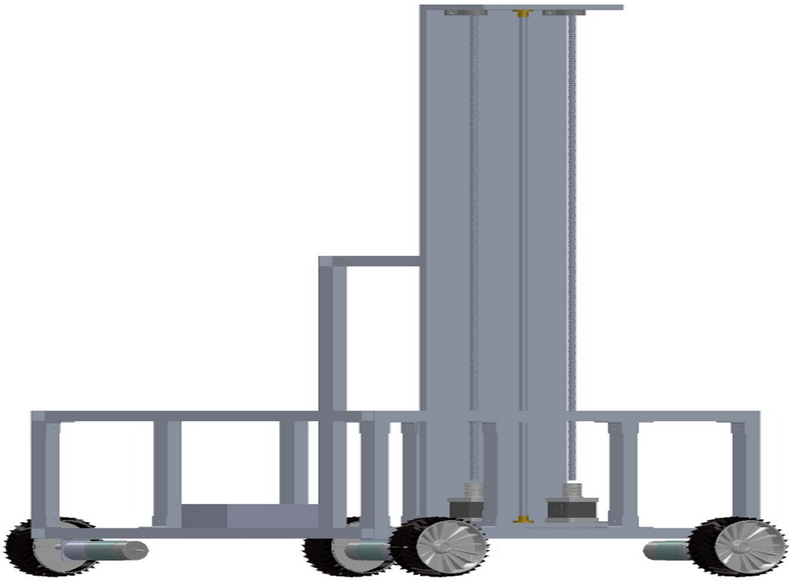

Figure 3.1 CAD Isometric View

TOP VIEW

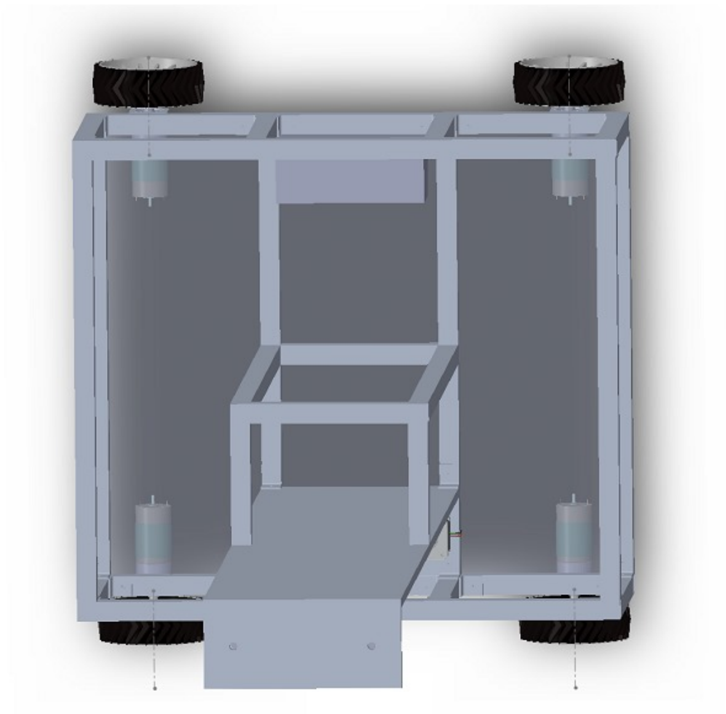

Figure 3.2 CAD TOP View

3.2.2 Wheels

The 10cm diameter by 4cm width robot wheels come in a set of one and are affordable, solid, and easy to install. These wheels are quite simple to put on motors because they feature an 8mm hole for a shaft and a screw for fitting.

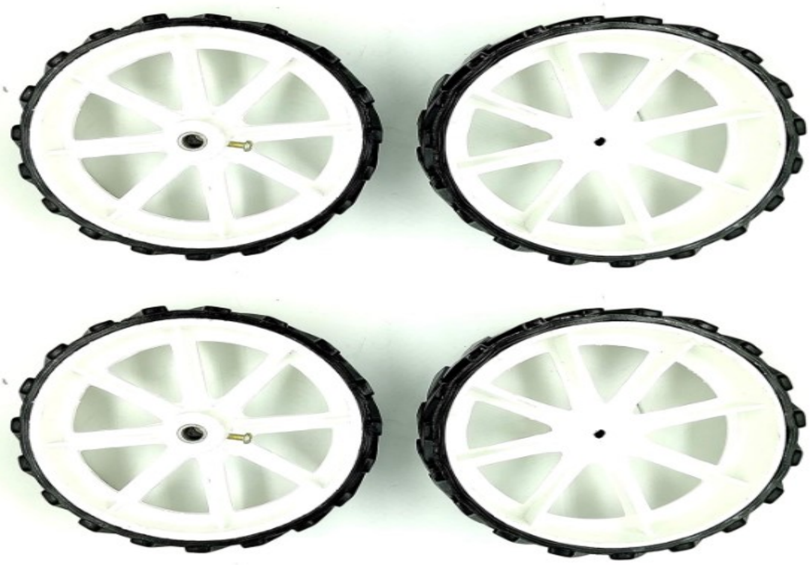

Figure 3.3 Wheels

Diameter of Shaft: 7 mm.

Diameter of wheel: 100 mm.

40 mm is the wheel width.

5kg is the loading capacity per wheel.

Material: Rubber & ABS Plastic

3.2.3 Manipulator

Our manipulator's robust base, made of the same grade aluminum material, serves as its foundation. This gives the entire structure a strong foundation and guarantees dependability even in the most trying circumstances. A robust and stylish 10mm-thick aluminum panel sits above the manipulator to give you a sturdy surface on which to perform your operations.

This device's vertical movements are powered by the well-known NEMA 17 Stepper Motor, which is well-known for its dependability and accuracy. When used in conjunction with lead screws, this motor provides smooth vertical displacement control, allowing you to perform jobs with exactitude.

Strategic integration of limit switches into the design has been implemented to guarantee both safety and accuracy. These switches protect the integrity of your operations by acting as essential checkpoints that avoid overextension. You may operate with confidence knowing that your manipulator will constantly prioritize safety and provide great performance with these precautions in place.

Figure 3.4 Fabricated Manipulator

3.2.4 FABRICATED MODEL OF MOBILE ROBOT

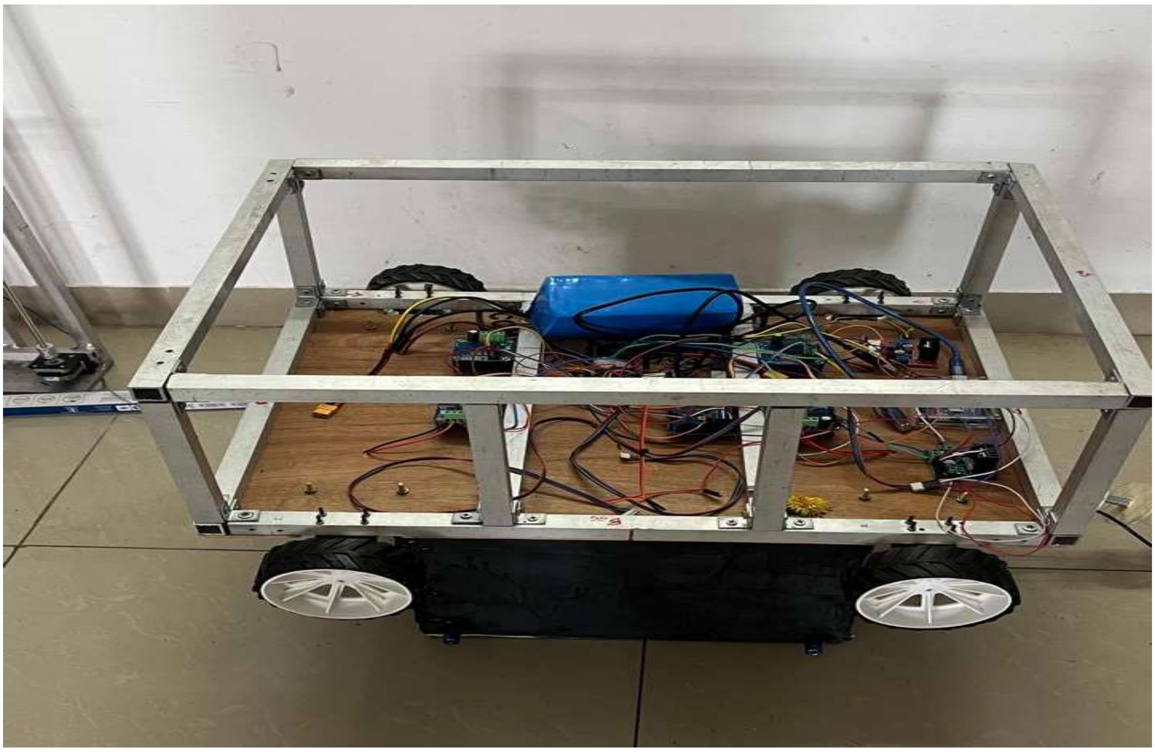

Figure 3.5 Fabricated Mobile Robot

3.2.6 COMPLETE MODEL

Figure 3.6 Complete Fabricated Model

3.3 ELECTRICAL DESIGN

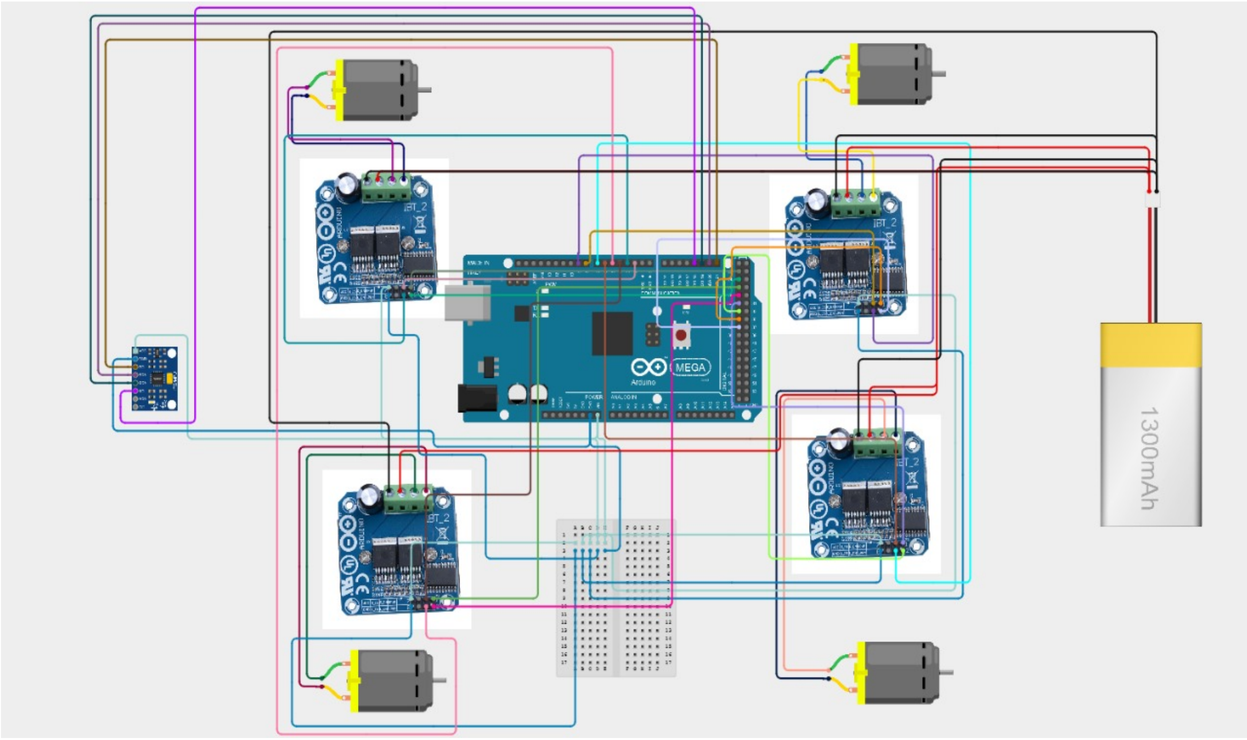

Figure 3.7 Circuit Connection For Motors to Arduino Mega

The electrical design of our Library Assist Robot is an incredible feat of functionality and integration, painstakingly constructed to provide smooth operation and cutting-edge capabilities.

Let's start by discussing the motor control system. For the robot to be able to move and maneuver, four precision-encoded motors are smoothly interfaced with their corresponding motor drivers. By serving as a bridge between the Arduino microcontroller and the motors, these drivers enable exact control over the motors' direction and speed. These motors can perform complex movements with extreme precision by integrating with the Arduino, allowing the robot to travel easily around the library.

Arduino coordinating the coordinated movements of every interconnected element. The Arduino connects to the motor drivers using a variety of I/O ports, allowing for real-time control over the robot's movement. It also creates a crucial communication channel with the Raspberry Pi, which makes it easier for the two devices to coordinate and exchange data.

The brain of our self-contained robot is the Raspberry Pi, which has sophisticated processing powers. By means of a connection to the Arduino, sensor data is received, and high-level commands are issued to control the robot's actions. Real-time mapping and robot localization within the library space are made possible by the Raspberry Pi's incorporation of a Lidar sensor. By using this mapping data for path planning, the robot can navigate independently, avoiding obstacles and finding the best route.

Furthermore, an infrared sensor is integrated into the design to improve safety and obstacle avoidance. This sensor is placed strategically on the robot's chassis to identify impediments in its path and initiate the necessary movements to prevent collisions.

Two NEMA 17 Stepper Motors are used in the manipulator portion to regulate the lead screw's movement. These motors, when paired with limit switches, guarantee accurate positioning and inhibit the manipulator arm from being overextended.

In conclusion, the electrical architecture of our Library Assist Robot skillfully combines sensor input, motor control, and autonomous navigation to provide a comprehensive and effective library automation solution.

3.3.1 Sizing of Motors

To ensure maximum performance and efficiency, it is essential to select the appropriate motor for your application. The following are important things to take into account when choosing a motor for your library assistance robot:

- Required torque
- speed
- power supply
- Feedback and control

Torque calculation

Required Speed- 100 rpm

wheel Speed=100 revolutions per minute

Wheel Diameter=100 mm

Payload/Expected weight to carry=25 kg

Dimension:-

length -45 cm

breadth - 55 cm

height - 120cm

1 Rev = 2 X π X R

=2 X 22/7 X 50

=314 mm

=3.14 cm

Wheel Speed:

=100π cm/min

=100π 10^-2m/60 sec

= π/60 m/s

SKETCH

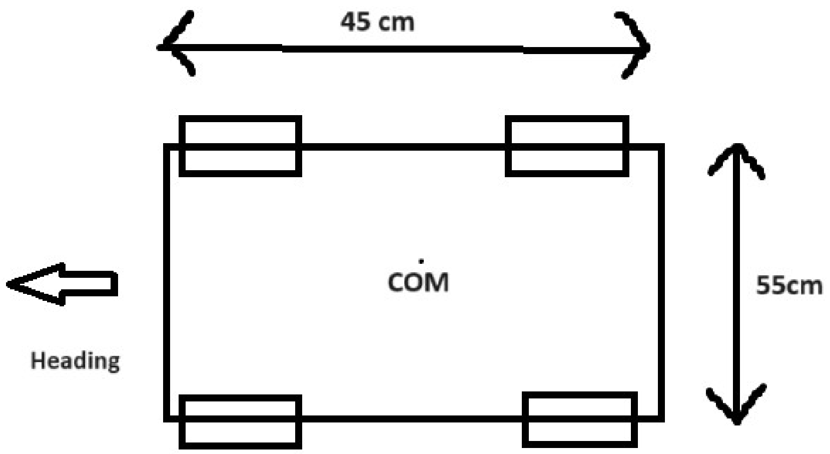

Figure 3.8 Reference Mobile Base

Total Torque:

= 25 X (55/2) Kgcm

= 687.5 Kgcm

Torque Per Motor:

greater or equal to 687.5 / 4

greater or equal to 171.87 Kg Cm Per wheel

Rated Torque 171.87 Kgcm

For the Wheel to have 100 rpm,

i.e π/60 m/s speed

Rated Torque:

The motor should g=have greater than 171 Kg Cm Torque of 100 rpm speed

=171 N-cm

3.3.2 Stepper motor selection and control

A NEMA 17 stepper motor is a kind of stepper motor that complies with National Electrical Manufacturers Association (NEMA) specifications and has a standardized mounting flange and shaft size. These motors are widely employed in many different applications where accurate rotation speed and angular position control are necessary.

- NEMA 17 describes the motor's standard dimensions, which include the shaft diameter (5 mm) and mounting flange size (1.7 x 1.7 inches, or 42.3 x 42.3 mm).
- Usually, these motors have 200 steps each revolution with a step angle of 1.8 degrees per step. Finer resolution can be attained, nevertheless, by using microstepping.
- NEMA 17 stepper motors come in a range of lengths and torque ratings, with differences in rated current, holding torque, and other features.
- following calculation to get the torque needed for a NEMA 17 stepper motor:

Following calculation to get the torque needed for a NEMA 17 stepper motor:

Torque = Force X Radius

Where

The necessary torque is expressed in Newton-meters, or Nm.

In Newtons (N), force is the amount of force needed to accomplish a given task, such lifting a load.

Radius, measured in meters (m), is the effective radius at which force is delivered. This radius is usually the lead screw or pulley's radius when attached to the motor shaft.

In our case-

Expected Load - 6 Kg

1 Kg = 9.81 N

so, 6 Kg = 58.86 N

Lead Screw radius = 8 mm

= 0.008 meter

Torque = 58.86 X 0.008

= 0.47 N/m

3.3.3 Motor

In our Project we are using 2 types of motor -

- 12V Dc High Torque Encoded Motor
- NEMA 17 Stepper motor

3.3.3.1 Rhino Motor

12V DC geared motors operating at 100 RPM for robotics applications. It produces a powerful 27 kg cm torque. The motor has an off-center shaft and a metal gearbox. With 9360 counts per revolution, the integrated quad encoder provides precise position and speed control.

Figure 3.9 Rhino Motors

Features-

- Motor with quad encoder, 1
- 8000 RPM base motor,
- 9360 counts per revolution,

- metal gearbox, and metal gears.
- Gearbox diameter: 37 mm, shaft diameter: 6 mm, thread hole size: M3.
- Motor Dimensions: Diameter 28.5 mm, Length 87 mm,
- No Shaft Shaft length: 30 mm; weight: 170 g; centimeter Holding
- Torque Maximum load current of 7.5 A, No-load current of 800 mA

Pinouts for Encoder Motors:

- Black for Motor-
- Red for Motor+
- Green for Gnd
- Blue for VCC +5 V DC
- Yellow for Enc A
- White for Enc B

3.3.3.2 Stepper Motor -

NEMA 17 42HS48-2504 AF-01 Stepper Motor, D Type, 5.6 kg/cm, with detachable 72 cm cable

Figure 3.10 NEMA 17 Stepper Motor

With a detachable 72-CM cable, the 42HS48-2504 AF-01 NEMA 17 5.6 kg-cm stepper motor has a high torque and is intended for precise motion control applications. It has a torque rating of 5.6 kg-cm, which means that it can rotate with significant force. Under the NEMA 17 category, this round-type motor has an easily removable 72-cm wire for easy installation. It is appropriate for a variety of automation, robotics, and CNC applications where precise positioning and dependable performance are needed because of its small size and sturdy build.

Features -

- NEMA 17 categorization for mounting dimensions that are standard.
- 5.6 kg-cm of high torque is the rating.
- motor design in the round style.
- Includes a 72-cm detachable cable for simple installation.
- Sturdy construction and small dimensions.
- ideal for situations requiring precise motion control.
- Ideal for CNC, robotics, and automation projects.
- Offers dependable performance and precise placement.

Specification –

Holding Torque Rating:	5.6 kg-cm
Step Angle (Degree)	1.8
Model No.	42HS48-2504 AF-01
Rated Voltage (V)	4
Rated Current (A)	2.5
Number of Phase	2
Resistance (Ω)	1.6+-10%
Inductance (mH/Phase)	1.8+-20%
Holding Torque (kg-cm)	5.6
Shaft Type	D-type
Length (mm):	42
Width (mm):	42

3.3.4 Control Of DC Motors with BTS-7960 Motor Driver

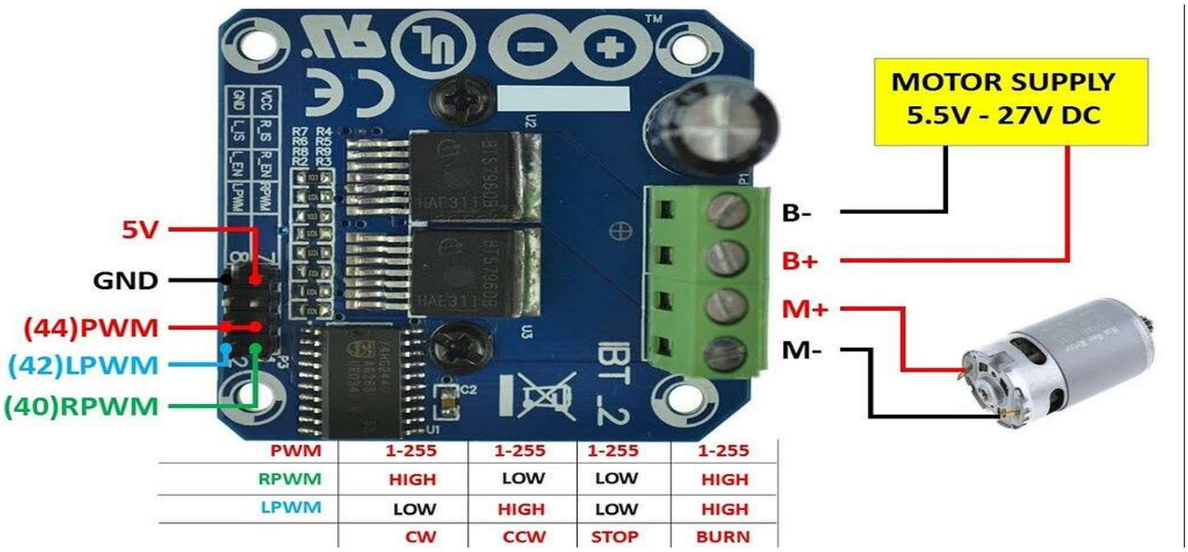

Figure 3.11 Controlling Of DC Motors with BTS-7960 Motor Driver

With a BTS-7960 motor driver, you would normally take the following actions to operate DC motors:

Identifying the Motor Driver BTS-7960: The BTS-7960 is an H-bridge motor driver integrated circuit that has a large current capacity and can drive DC motors in both directions. Typically, it's packaged as a module with screw terminals for simple connection.

Link: Attach the BTS-7960 motor driver to your DC motor. For the motor connection, you usually have two connections, one for each direction (commonly labeled 'A' and 'B'). To power the motor driver itself, you should also connect ground (typically labeled 'GND') and power (commonly labeled 'Vs').

Control Inputs: To control the motor's direction and speed, the BTS-7960 features control inputs. Labels such as "IN1" and "IN2" for one direction and "IN3" and "IN4" for the other are frequently applied to them.

Pulse Width Modulation (PWM): PWM is typically used to regulate the motor's speed. The 'IN' pins can be used to link the PWM signal from a microcontroller or any other PWM source. The PWM signal's duty cycle can be adjusted to alter the motor's speed.

Direction Control: You may regulate the direction of the motor spinning by properly adjusting the logic levels of the 'IN' pins. For instance, the motor may turn in one direction if IN1 and IN2 are set high, and in the other direction if IN1 and IN2 are set low.

Current Limitation: Overcurrent protection and current sensing are frequently included with the BTS-7960. This is helpful in preventing harm from excessive current to the motor and motor driver.

ARDUINO MEGA CONNECTION -

1. **HARDWARE SETUP**

MOTOR CONTROL SETUP

MOTOR DRIVER PINS	DIGITAL PIN NO
M1RPWM	2
M1LPWM	3
M1REN	22
M1LEN	24
M2RPWM	4
M2LPWM	5
M2REN	26
M2LEN	28
M3RPWM	6
M3LPWM	7
M3REN	30
M3LEN	32
M4RPWM	8
M4LPWM	9
M4REN	34
M4LEN	36

ENCODER SETUP

ENCODER PINS	DIGITAL PIN NO
M1A	44
M1B	45
M2A	40
M2B	41

M3A	42
M3B	43
M4A	18
M4B	19

3.3.5 Control of Stepper Motor with L298 Motor Driver

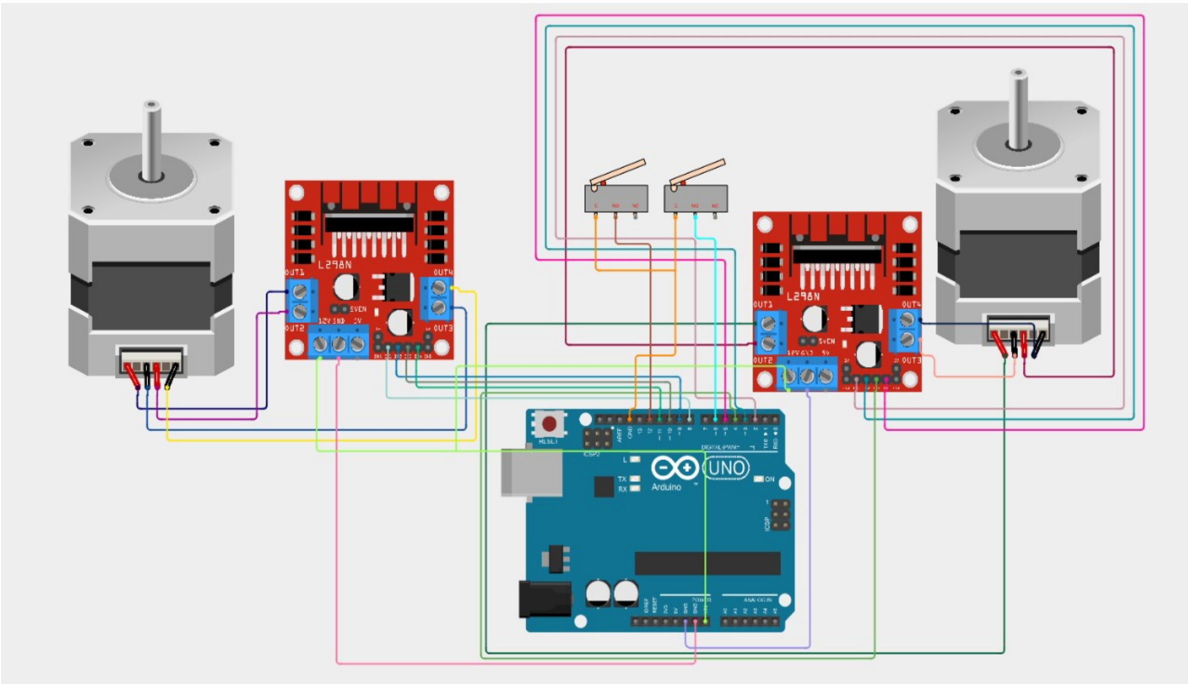

Figure 3.12 Controlling Of Stepper NEMA-17 with L298 Motor Driver

Using an L298 motor driver to control a NEMA-17 stepper motor requires a somewhat different methodology than controlling a DC motor. Here's a broad overview:

- To operate DC motors or bipolar stepper motors, the L298 motor driver is a twin H-bridge motor driver integrated circuit. Its accessibility and ease of use make it a popular choice.
- Connect the L298 motor driver to your NEMA-17 stepper motor. Four or six wires, which are normally attached to the motor driver's output terminals, are present in NEMA-17 motors. For the precise wiring schematic, consult the datasheets of the motor and driver that you are using.

- Control Inputs: Each motor on the L298 has two control inputs. The stepper motor has two control pins for per coil. You can vary the direction of the motor's step by adjusting the logic levels of these pins.
- Microstepping: Since the L298 does not come with native microstepping capability, you will usually have to run the motor in full-step mode. A stepper motor driver that supports microstepping or external circuitry can be used to accomplish microstepping.
- Sequence control: Stepper motors operate in steps, where each step is associated with a certain sequence of coil energization. To get the stepper motor to revolve, you must drive the L298's control inputs in the proper order.
- Timing: The motor's speed is set by regulating the intervals between steps. By altering the interval between each step, you may regulate the speed.

3.3.6 Limit Switches -

In stepper motor control systems, limit switches are often used to set a reference position or identify the boundaries of motion. The following explains limit switches and how to link a stepper motor and Arduino to them:

Figure 3.13 Micro Limit Switch

Limit switches are mechanical switches that become active upon contact with an object. - They are frequently employed as end-of-travel or reference position sensors in motion control systems, where they are utilised to detect the presence or absence of an object.

SETUP-

Connect the L298 Motor Driver to Arduino: To control the stepper motor, connect the L298 motor driver's control pins to the Arduino's digital pins.

Attach the L298 Motor Driver to the Stepper Motor: Attach the stepper motor coils to the proper L298 motor driver output pins.

Limit switch connections to Arduino: Connect the limit switches to the Arduino's digital input pins. Additionally, every switch needs to be linked to the Arduino's ground (GND) pin.

Power Source: Link the stepper motor's and the L298 motor driver's power supplies.

1. **HARDWARE SETUP**

MOTOR CONTROL SETUP -

MOTOR DRIVER PINS	DIGITAL PIN NO
D1In1	2
D1In2	3
D1In3	4
D1In4	5
D2In1	8
D2In2	9
D2In3	10
D2In4	11

LIMIT SWITCH	DIGITAL PIN NO
SWITCH 1	6
SWITCH 2	12

3.4 SENSORS

Sensors play an important role in autonomous mobile robots they extract raw data from the environment and process the signals.Sensor fusion between lidar encoders and imu is done in our project.

3.4.1 LiDAR

The 360 Laser Distance Sensor LDS-01, often called the Lidar 360 LDS 01, is a 2D laser scanner made specifically for navigation and SLAM (simultaneous localization and mapping) activities in a variety of robotic applications. It can do a 360-degree ambient scan, collecting information that is essential for creating maps and robotic orientation.

Figure 3.14 Lidar

General Specification -

Items	Specifications
Operating supply voltage	5V DC ±5%
Light source	Semiconductor Laser Diode(λ=785nm)
LASER safety	IEC60825-1 Class 1
Current consumption	400mA or less (Rush current 1A)
Detection distance	120mm ~ 3,500mm
Interface	3.3V USART (230,400 bps) 42bytes per 6 degrees, Full Duplex option
Ambient Light Resistance	10,000 lux or less

Measurement Performance Specification

Items	Specifications
Distance Range	120 ~ 3,500mm
Distance Accuracy (120mm ~ 499mm)	±15mm
Distance Accuracy(500mm ~ 3,500mm)	±5.0%
Distance Precision(120mm ~ 499mm)	±10mm
Distance Precision(500mm ~ 3,500mm)	±3.5%
Scan Rate	300±10 rpm
Angular Range	360°
Angular Resolution	1°

3.4.2 IMU (Inertial Measure Unit)

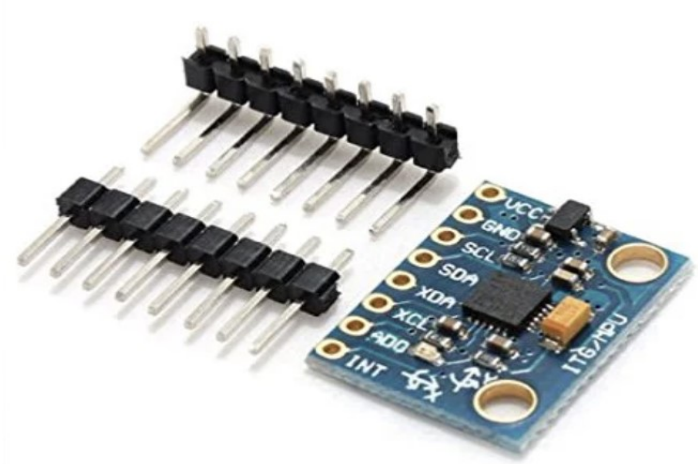

Figure 3.15 IMU

The MPU-6050 is a multipurpose sensor module that integrates a three-axis gyroscope and accelerometer onto a single chip. This feature makes it ideal for motion tracking in a range of applications, including wearables and robotics. It has an inbuilt Digital Motion Processor (DMP) that can handle intricate 6-axis MotionFusion algorithms. By handling sensor fusion computations internally, the DMP lessens the strain on the host processor.

Features -

16-bit data output and a 16-bit AD converter incorporated into the chip.I2C Six or nine-axis MotionFusion data can be digitally exported in quaternion, raw data, rotation matrix, or Euler Angle formats.FSYNC, AD0, and CLK Selectable Solder Jumpers.Complex MotionFusion, sensor timing synchronization, and gesture detection are offloaded by the Digital Motion Processing (DMP) engine.Compass calibration and run-time bias are handled via embedded algorithms. User involvement is not necessary.digital temperature sensor with an output.

3.4.3 Quad Encoders

With a specification of 9360 Counts per Revolution (CPR), an Integrated Quad Encoder is a high-resolution tool for motion-related applications that require exact position and speed control. Known by the name quadrature encoder, this kind of encoder works by producing two output signals that are 90 degrees out of phase square waves. The direction and speed of the rotation can both be detected with this arrangement.

Figure 3.16 Quad Encoder

The capacity to offer incredibly specific feedback on shaft position—a critical feature for applications demanding high accuracy, such robotics and industrial automation systems—is the main benefit of using an encoder with a high CPR like the 9360. This kind of encoder can greatly improve performance in situations where precise control of motion and position is essential by enabling finer adjustments and greater control of mechanical components.

This type of encoder operates by generating a predetermined number of pulses that are uniformly spaced apart for each rotation of the encoder shaft. Systems can precisely track rotational positions and speeds because of the utilization of these pulses, which measure both the amount and direction of movement. A controller interprets the pulses the encoder emits in the A and B channels when it rotates in order to calculate the direction of motion and count the number of increments or decrements that indicate movement.

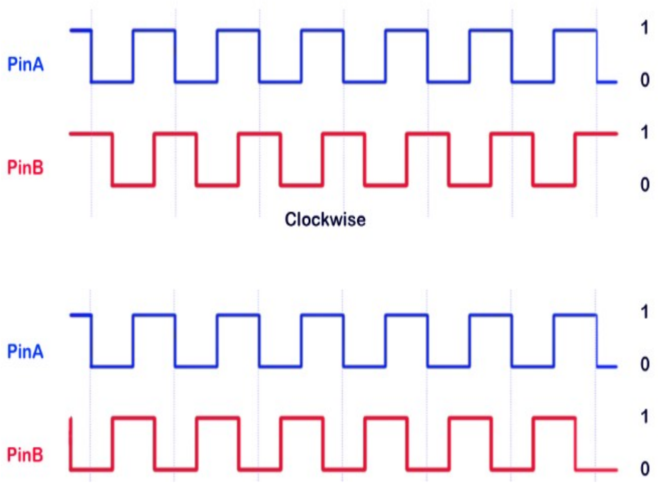

Figure 3.17 Pulse generated by Encoder

3.5 COMMUNICATION

In our model raspberry pi is the brain which acts as a master who commands over the other microcontrollers used . The pi is connected to a LiDAR,Arduino UNO and Arduino Mega.The lidar sensor helps in mapping and laser localization,and sends data to the raspberry pi .The Arduino UNO receives and sends signal to the pi .The arduino uno is connected to two L298D motor drivers to which two stepper motors and two limit switches are connected for the feedback and to set the position and direction of rotation of the stepper motors. The RFID scanner is also connected to the arduino uno.They get in action once the mobile robot reaches the desired position.The mega is connected to four bts 7960 motor driver and these motor drivers are linked to individual dc motors and these motors have individual encoders, which are responsible for odometry. The uno sends signals to the drivers, in response the movement in the motor takes place , the position of the motor or the steps the motor have encountered is been recorded by the encoders,send feedback to the uno and passes on the data to the pi and the loop goes on until the desired position is reached.The mega is also connected with an imu which is responsible for the velocity calibration.

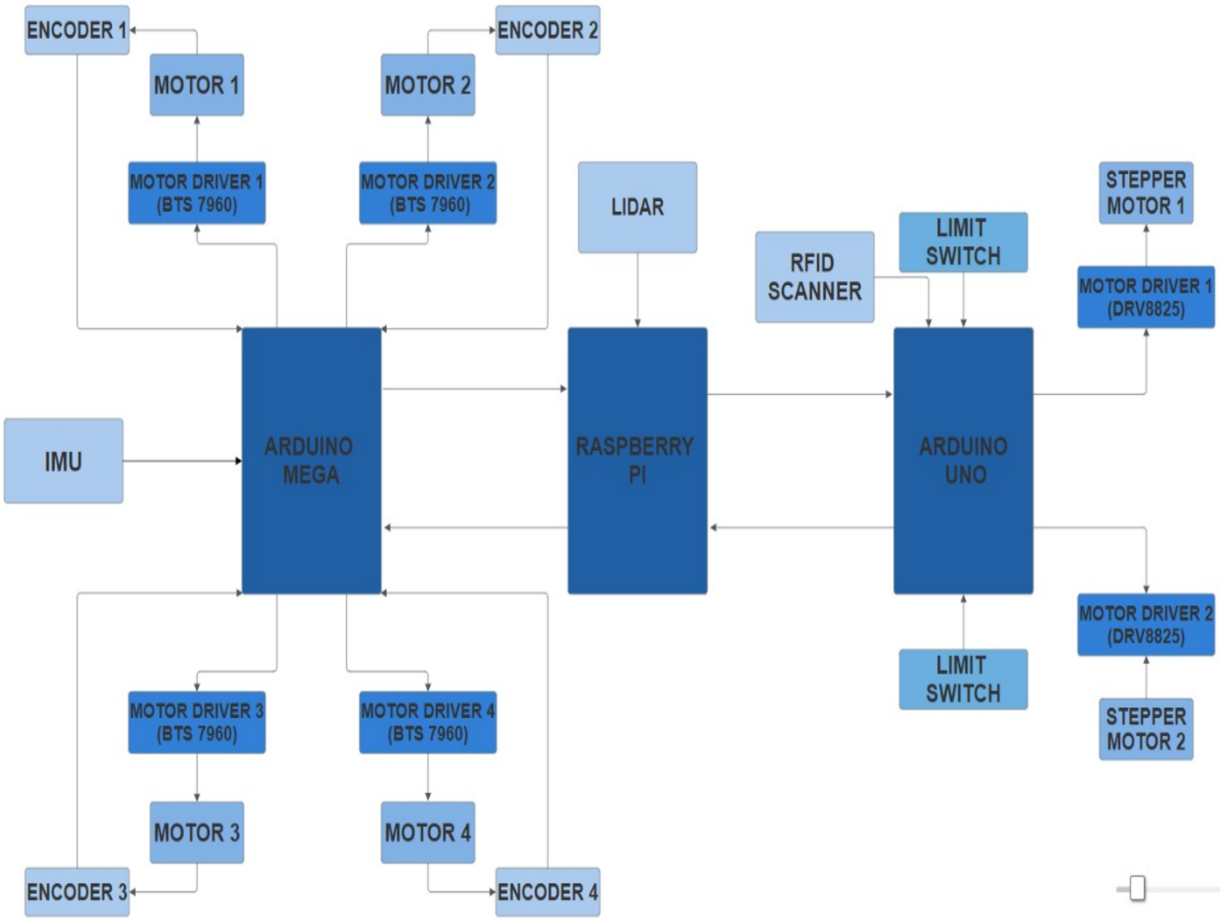

Figure 3.18 Communication Diagram

CHAPTER 4

ROBOT MOBILITY

4.1 GAZEBO SIMULATION

In the process prototyping simulation plays an important role which helps in visualizing the working of the model before implementing it in the real time and this prevents also prevents wastage of components and avoid malfunctioning of the robot and if so this can be rectified before in hand and prevents damages to the robot as well as the human beings.

In ROS gazebo software allows us to perform robust 3D simulation where we can create a virtual environment as per the requirement and add our robot model, to the robot model we can integrate sensors as per our need and perform simulation and check the working of the code as well as the sensors and do the necessary changes if things goes wrong.

4.1.1 Steps to perform simulation

1.First we have to create a world in the gazebo and the models required and create the setup then save the environment.

2.Once the environment is created, make that into a launch file.

roslaunch mobilebase_gazebo mobilebase_empty_world.launch

3.Then add the robot in the environment by launching your urdf file.

4.Then run to related publishers and subscriber nodes and scripts to move the robot as well as collect data from the sensors.

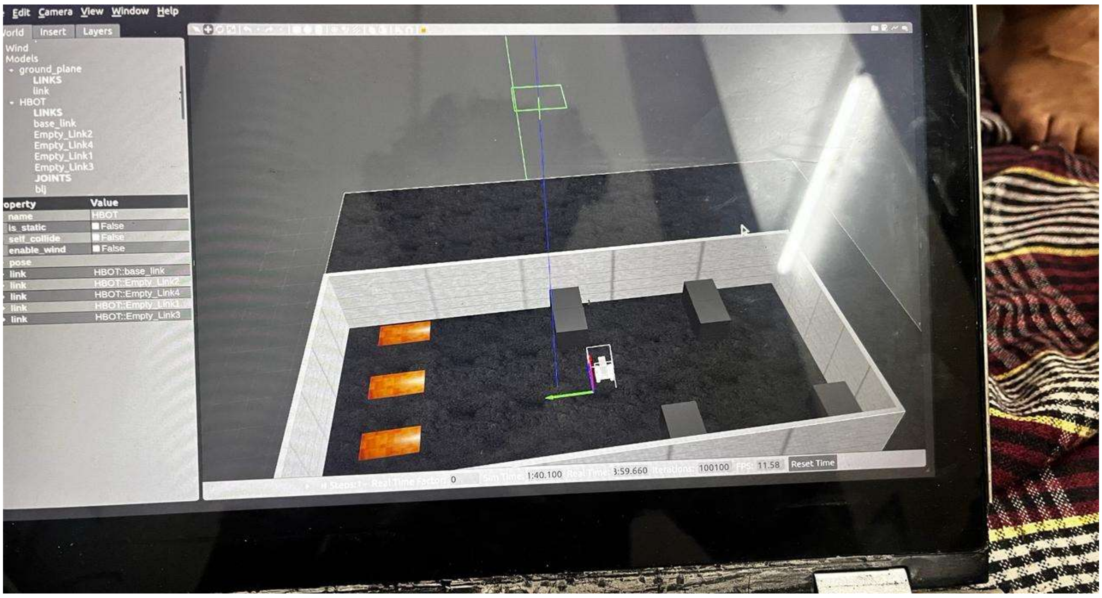

Figure 4.1 Gazebo Simulation

4.1 MAPPING :

In this project we have used surface contour mapping which finds its application in various sectors where topographic exploration of unknown surroundings is required. Exploration of the 3D environment and its 2D mapping are the key functions of our mobile robot . Our mobile robot is designed to traverse through their surroundings and provide the fundamental map of the contour surfaces present in the surroundings. Such exploration by mobile robots are semi-autonomous, robot scans the 3D environment present around them and give us a basic overview of their surroundings by 2D mapping.The robot explores the unknown 3D surroundings in which it is placed and provides the 2D surface contour plot of the scanned 3D environment and maps the 3D environment.For mapping we have used 360 Laser Distance Sensor LSD-01.

We have used ROS packages such as hector slam to generate the map in ROS and to visualize the map we use RVIZ. In RVIZ under laser scan topic we can get the map ,while mapping to move the mobile robot we have to teleoperate the robot.

4.1.1 Steps to generate map

1. In ROS we first have to include the LidAR publisher node to run the lidar.
   roslaunch hls_lfcd_lds_driver view_hlds_laser.launch
2. Then include the hector slam package which helps to generate the map.
   roslaunch hector_slam_launch tutorial.launch
3. In RVIZ select the fixed frame as map and under topics add laser scan after this visualization of map takes place and the trajectory of the mobile robot is also recorded.
4. The movement of the mobile robot is done through teleoperation.
   rosrun teleop_twist_keyboard teleop_twist_keyboard.py
5. To save the map we have to use rosrun map_server map_server ~/major_ws/src/map.yaml and this helps to save the map in the required location.
6. To open the required map we have to use a launch file to open the map in RVIZ.

4.1.2 Nodes involved in mapping

hector_mapping

hector_mapping is a node for LIDAR based mapping which helps us to generate map without odometry and low computational resources are required.

Subscribed Topics

tf (tf/tfMessage)
Transforms necessary to relate frames for laser, base_frame

scan (sensor_msgs/LaserScan)

Transforms the laser frame and data to visualize in Rviz under the above topic

Published Topics

map_metadata (nav_msgs/MapMetaData)

Gets the map data from this topic, which is linked, and updated periodically.

map (nav_msgs/OccupancyGrid)

Gets the map data from this topic, which is linked, and updated periodically.

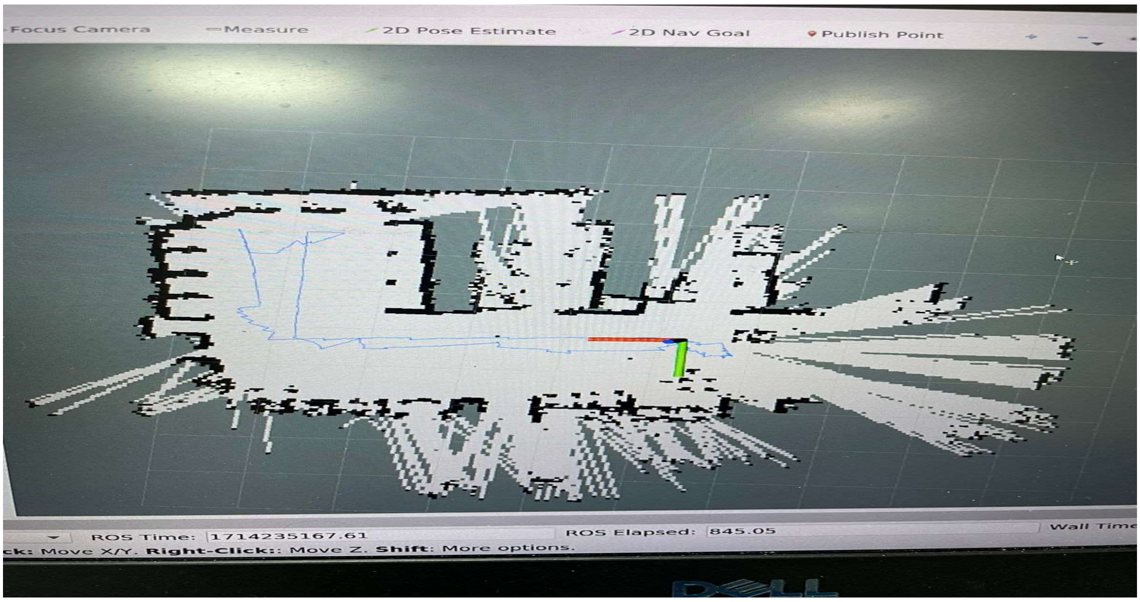

Figure 4.2 Hector Mapping

4.2 NAVIGATION :

The ROS Navigation Stack is used in 2D maps, for mobile robots with a non-holonomic and holonomic drive, and a planar laser scanner. It uses odometry, sensor data, and a goal pose to give velocity commands.The node move_base plays an important role in ROS Navigation Stack.It uses a global and local planner to reach the navigation goal and coordinates communication within the navigation stack.Sensor information is collected (sensor sources node), then put into perspective (sensor transformations node), then combined with an estimate of the robots position based on the starting position and the current position (odometry source node). This information is published so that "move_base" can calculate the trajectory and pass on velocity commands (through the base controller node) also helps in obstacle detection and avoidance.

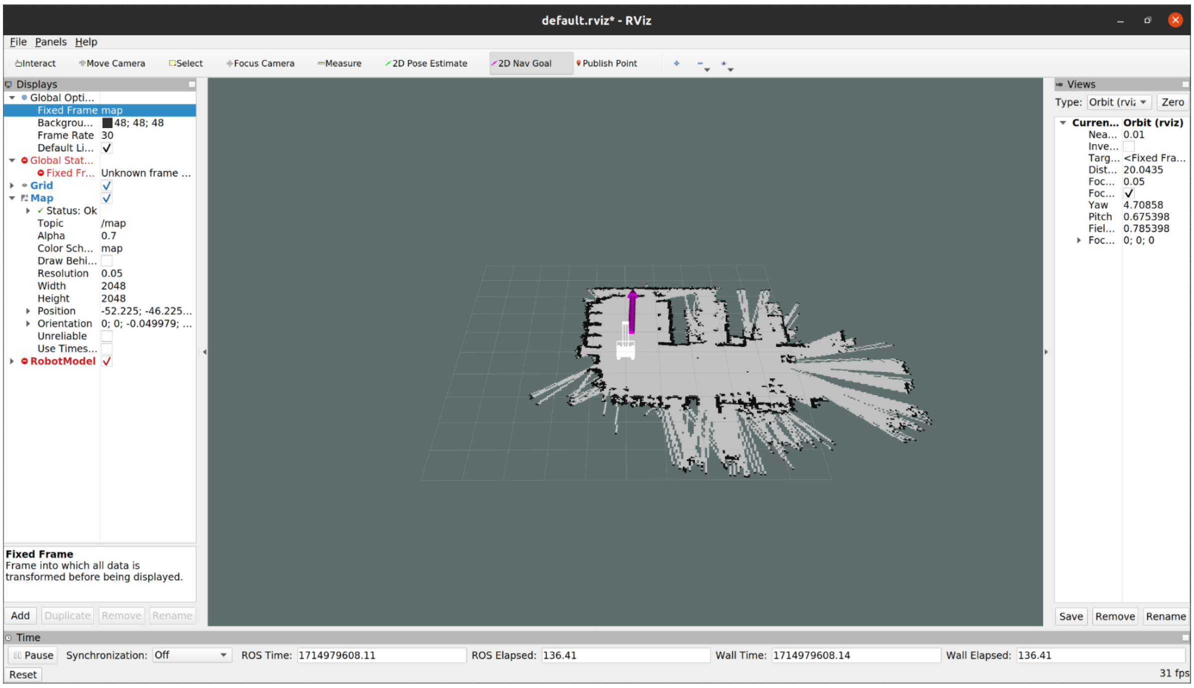

Figure 4.3 Autonomous Navigation In RVIZ using move_base

4.2.1 The Nodes involved in Navigation:

move_base

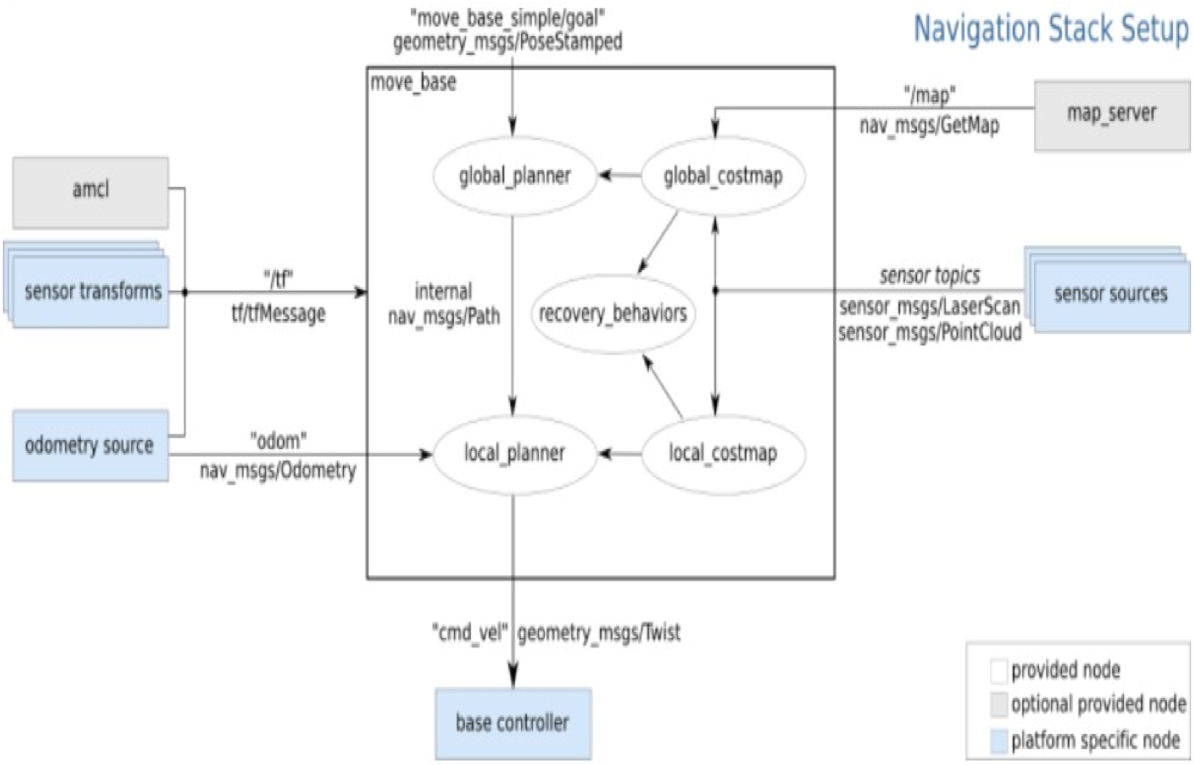

Figure 4.4 Nodes Involved in move_base

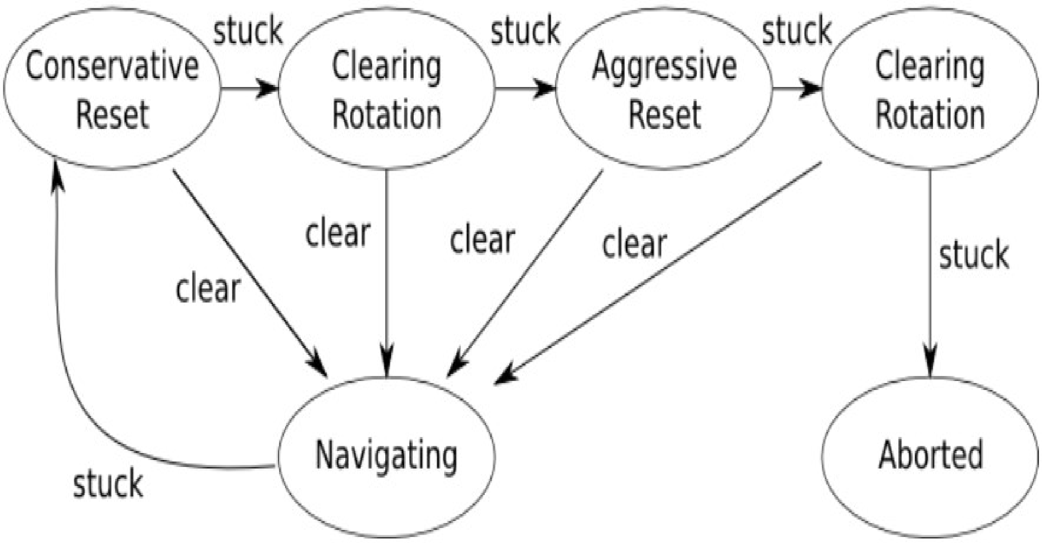

Figure 4.5 Behavior of our mobile robot during navigation while using move_base

Action Topics in move_base

move_base/goal (move_base_msgs/MoveBaseActionGoal)
helps the bot to move towards the goal in the map.

move_base/status (actionlib_msgs/GoalStatusArray)

gets the status information on the goals that are sent to the move_base action received by the mobile robot.

Subscribed Topics in move_base

move_base_simple/goal (geometry_msgs/PoseStamped)

Provides a non-action interface to move_base for users that don't require tracking of the execution status of their goals.

Published Topics in move_base

cmd_vel (geometry_msgs/Twist)
Set of velocity commands meant for movement of the mobile robot.

4.3 LOCALIZATION

The process in which the mobile robot obtains the position as well as the direction in which it is moving. In this project, the environment is fixed and closed. We have used LiDAR, IMU, and encoders for localization. In our project, we have focused on laser-based localization. Sensor fusion plays a vital role in localization. Sensor fusion is the process of merging data from multiple sensors. In autonomous mobile robots, perception refers to the processing and interpretation of sensor data to detect, identify, classify, specify and track objects.

Sensor fusion and perception enables an autonomous vehicle to develop a 2D model of the surrounding environment that feeds into the mobile robot's control unit. To retrieve books of the different genres we have used virtual landmarking, individual genres will have a unique point given in the map, and a home position is set, every time the mobile robot can start and end at the same place. The main motive of home position, so that if the robot fails to locate itself in the environment or gets lost it can move to its home position and restart.

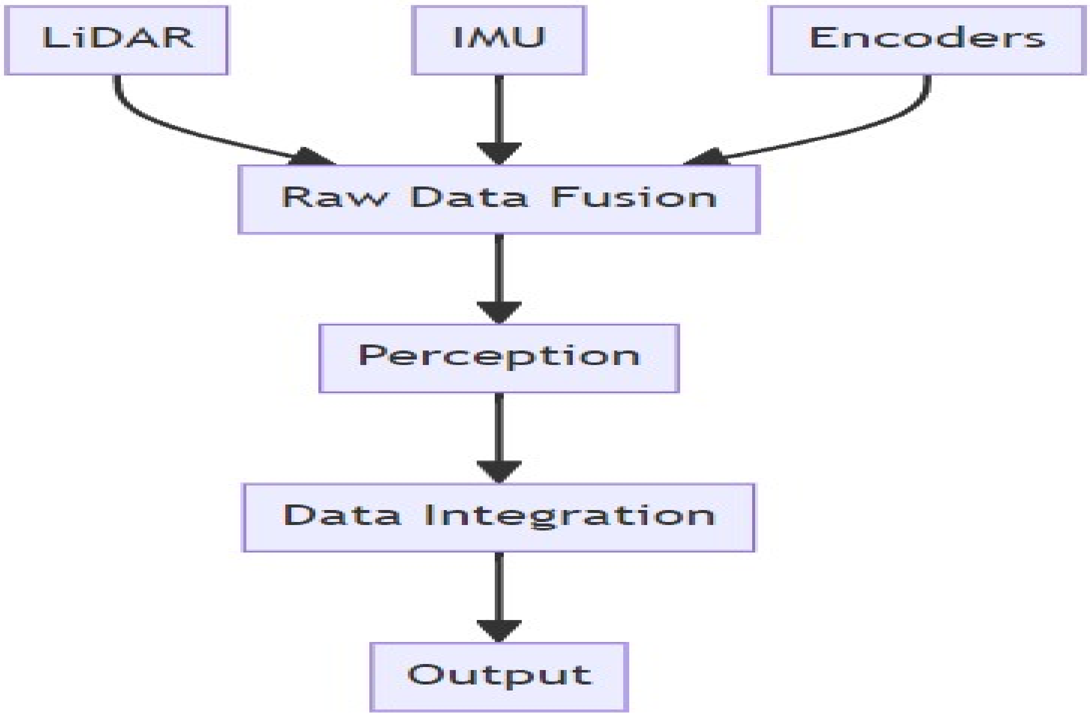

Figure 4.6 Sensor Fusion For Localization

CHAPTER 5

CONCLUSION AND FUTURE WORK

5.1 CONCLUSION

In conclusion , the smart library assistant robot helps in retrieval of books in the library. The robot first receives commands from the user to search, locate, retrieve the book in the library. Once the book name has been identified by the robot it starts searching for the genre of the book so that the mobile robot can reach the genre and reduces time spent in searching for the book. To reach the genre we have used virtual land marking so that the mobile robot can reach the specific rack. For searching the book, we have used an RFID scanner and each book has RFID tags with individual unique code. Once the mobile robot locates the book then the manipulator moves up and down and then the gripper retrieves the book from the book-shelf and brings the book to the home position.

5.2 FUTURE WORK

This project can be extended further by adding a display and a customized user-interface where the robot greets the user and asks which book the user needs. Artificial intelligence can be integrated so that the robot and the user can communicate easily and the whole process will be faster.

Another expansion of this project can be book stacking. As of now this robot can only retrieve the book but cannot stack it back in the same place. Placing the book back on the rack at the same place can be a function that can be integrated into the robot using ROS.

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