International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 06 Issue: 09 | Sep 2019 www.irjet.net p-ISSN: 2395-0072

Design and Development of Library Management Robot: Part 1 Development of Travelling Robot with Omni Directional Wheel

Pranav Bairagi[1], Rushikesh Ghate[2], Swarant Patil[3]

[1,2,3]*Mechanical Engineer, Pune Maharashtra India*

Abstract - *The said paper is the preliminary part of the library management robot. This part consist of a mobile robot which is used to pick the book from the user and send it to the shelve robot. The robot is equipped with Omni direction wheel coupled with planetary geared dc motor. The robot is fully autonomous and the path tracking is carried out using the line sensing array and the book is scanned using the barcode reader. A pneumatic gripper along with lead screw mechanism is used to lift the books from the user. The portable air reservoir is used to operate the pneumatic gripper. The lead screw mechanism is operated using the planetary geared motor with encoder. The transreceiver is used to communicate with the shelve robot which shares the barcode information with each other. The main application of the robot is of pick and place mechanism.*

Key Words: Lead screw, Line Sensing Array, barcode reader, pick and place robot

1. INTRODUCTION

In library, the management of books is very complication and timing costing. The location of books could be altered by librarian, students, teachers and any one around the library. Therefore, allocating a book is not an easy task in big library [1]. Recent years have seen an increased awareness of the need for lifelong learning, and major growth in knowledge based industries. Along with this, the general public has come to make greater use of existing general library facilities, and to expect a higher level of Service from them. Consequently, librarians and other skilled library workers are now expected to provide many highly specialized Services that require detailed knowledge of publications and library Science. In the majority of the libraries in existence today, however, a large part of the normal workday of Such skilled library staff members is taken up with handling library books: i.e., finding a book desired by a library patron, taking it off the shelf, and placing it in the hands of the user who requested it; and taking books that have been returned by users, carrying them to the bookracks, and returning them to their proper locations on the shelves [2].

2. FLOWCHART:

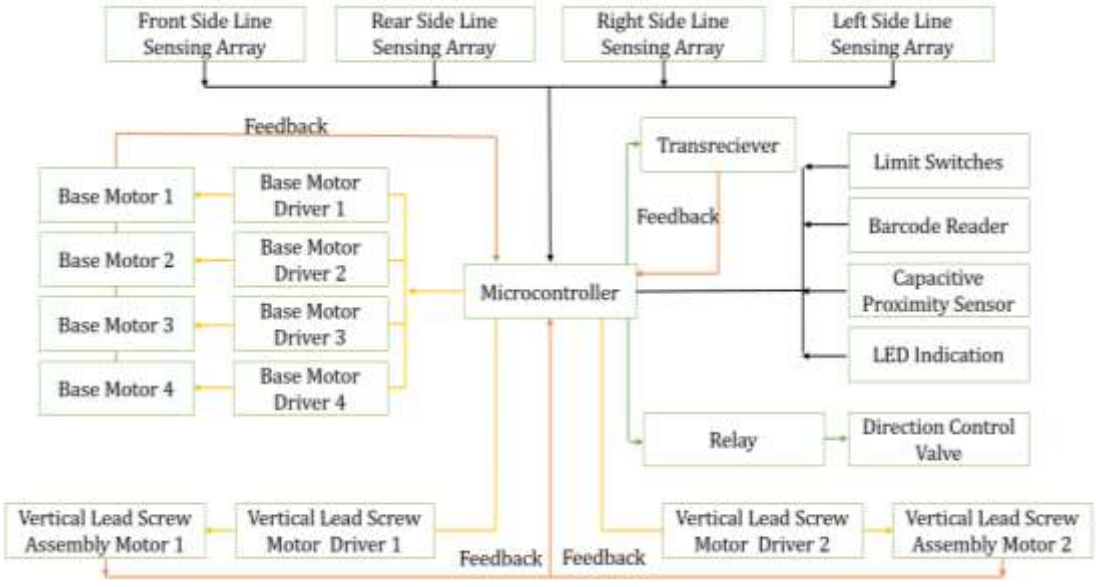

Figure 1: Electronics Flowchart Robot Side

At first the user gives the book to the mobile robot by keeping the book in the reception book stand. The robot by using the line sensing array travels towards the stand. As soon as the robot comes towards the stand with the help of proximity sensor it detects the book by moving the gripper in front of the each section of the book stand. Whenever the book is been detected, the pneumatic gripper is been activated and book is been grabbed. The robot is then moved towards the shelve robot by using the line sensing array. During the travelling the robot is uses the barcode reader which consist of the shelve number, column number and the row number of the book. With these information robot moves towards the respective shelves. The robot when comes near by the shelve robot, the shelve gripper is been detected by the proximity sensor and the book is hand it over to the shelve robot. To operate the vertical lead screw mechanism the robot uses the pwm signals which is then send to the motor driver, this motor driver is used to control the precise motion of the lead screw. The pneumatic gripper is operated using the directional control valve and relay board. Each of the wheel is equipped with the separate planetary geared motor. After each transfer or each sensor detection the led is been blinked for the user purpose to know that the action is been performed.

3. DESIGN CRIETRIA:

a. The robot should be mobile and should be travel in every location.
b. The weight of the robot should be less.
c. The robot arm should be travel in every direction with certain degrees of freedom.
d. Robot should detect the book stand, book shelve and the book's barcode.
e. Robot should be rigid enough.

4. DESIGN OF CHASSIS:

Type	Double Square lead screw support mechanism
Material Used	Aluminium Square Channel With 20 X 20 mm With 2 mm Thickness
Material Used	Commercial Grade
Chassis Fabrication Methods and Operation	Welding, Drilling, Bolting, Grinding and Cutting.
Base Chassis Length X Width	450 X 450 mm
Chassis Height	500 mm

a. There are three layers of the chassis, one is in parallel to second plains with a offset of 100 mm and third plain is perpendicular to the first two plains. Thus the manufacturing of the chassis is divided in to four stages.
b. At first the lower chassis is made using the square aluminium sections. The bars are cut into respective lengths and are ready to join. Before joining the channels the fixture is made and the channels are clamp together in order to avoid the angle error while joining and also the bending of the chassis parts.
c. At the same time the second layer of the chassis is made with same method and both are left to cool down. To eliminate the stress the chassis is stress removal processes are carried out.
d. Third layer which is perpendicular to the first two layer is allowed to manufacture but with different fixture and of different lengths. After manufacturing all the three different section are brought together.
e. The upper and lower section of square chassis is separated using the spacing square rods which is of 100 mm. This gap between the two sections is used to protect the circuit and battery while performing the operations.
f. The above L section of the chassis is connected at the 900 to the base chassis.
g. After this the fine edges were filleted and the bur was removed. Along with this, the surface of the aluminium was also grinded and polished which were damaged by welding.
h. Figure 2, Shows the 3D cad model of the robot chassis.

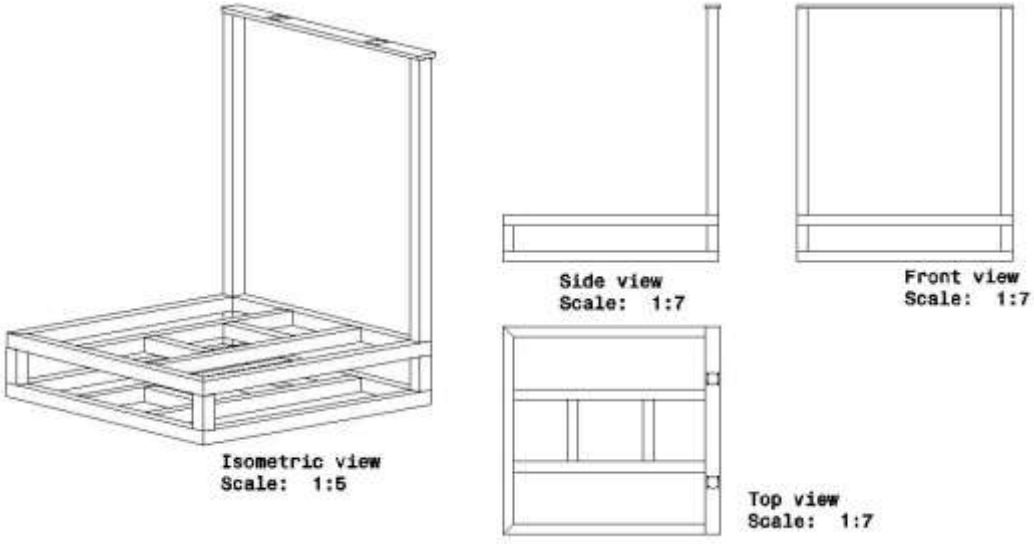

Figure 2: Isometric View of Chassis

5. DESIGN OF BASE MOTOR ASSEMBLY:

Wheel Type	Omni Wheels
Wheel Diameter	125 mm
Number Of Wheels	4
Shaft Type	N8
Wheel Coupling	Anti-Slip Type Of Flange Coupling
Motor Coupling	Anti-Slip Type of Flexible Coupling Outer Diameter- 25 mm Inner Diameter – 8 mm Length - 32 mm
Motor Type	Planetary DC Geared Motor With Rare Shaft Encoder
Torque / RPM	29.1 N cm / 400 RPM
Bearing	6100 Make- SKF
Motor Clamp Shape & Joining Process	L Shape & Bolting
Bearing Block Material	Aluminium Commercial Grade
Bearing Block Dimension	30 X 25 X 30 mm
Bearing Block Manufacturing Process and operation	Counter Boring and Milling

a. The base motor assembly was designed to reduce the vertical reaction develops due to weight of the robot, on to the motor's shaft.
b. The wheels were coupled with the flange type of anti-slip coupling.
c. The coupling was then coupled from the hub side to the transmission shaft. Which is passing through the bearing house assembly, this bearing house was made with the help of CNC operating. The end of the shaft is connected to flexible coupling.
d. The other end of flexible coupling is connected to motor shaft. The motor is mounted on L shaped clamp which was designed with laser cutting and sheet metal bending operation. Later L clamp was hardened to increase hardness.
e. There was three reaction force developed during motion and two reaction forces during steady condition. The vertical force was neutralized by the bearing house assembly. The force left was horizontal force along the axis of motor, this force is absorbed by the flexible coupling. The rotational force is created by the motor so no need to neutralize it.
f. All these assembly was fixed on the specific plate known as base plate, with the help of bolting. The plate was then join to the chassis with bolting at the places were the holes were drilled at the chassis stated above.

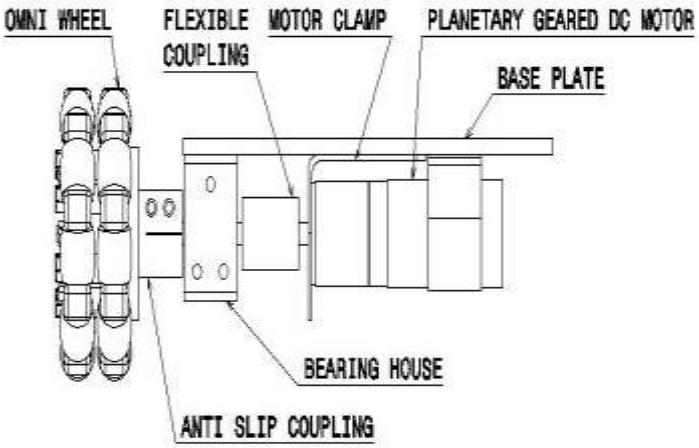

Figure 3: Detail View of Base Motor Assembly

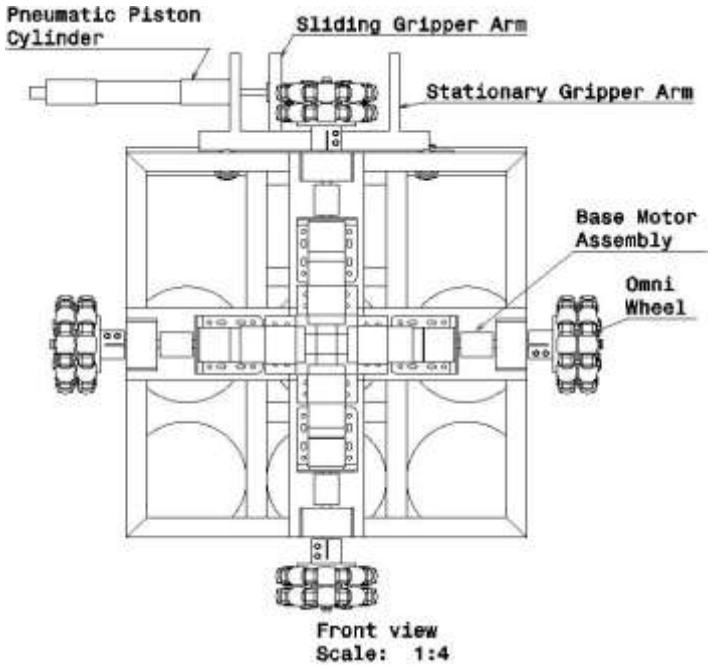

Figure 4: Base Motor Assembly

6. MOTOR SELECTION FOR VERTICAL MOTION ASSEMBLY:

Motor Type	Planetary DC Geared Motor With Rare Shaft Encoder
Torque Loaded Torque Stall Torque:	 72.63 N cm 526 N cm
RPM Of Base Motor	9000 RPM
Power Transmission From Base Motor To front shaft	Planetary geared Type Of Transmission Mechanism
Power Rating Stall Current Rated Current No Load Current Stall Voltage	 <11.7 Ampere <1900 mAmpere <280 mAmpere 24 Volt
Front shaft RPM	468 RPM
Weight Reduction Ratio Encoder PPR Number of motor used	430 g 1: 19.2 96 PPR 2

7. DESIGN OF VERTICAL MOTION ASSEMBLY:

Lead Screw Material & Manufacturing Process	Stainless Steel, Lathe Machine Operation.
Number Of Lead Screw Used	2
Lead Screw Joining Process With Chassis	Flexible Coupling
Bearing Type & Dimension	Single Row Deep Grove Ball Bearing, SKF, Outer Diameter- 32 mm Inner Diameter- 14 mm
Number Of Bearing Used	2
Lead Screw Thread Type Pitch Length Diameter Locking	Square 10 mm 450 mm 14 mm Self-Gliding

Number Of Start Nut Type & Material Number Of Nut As Arm	2 Aluminium 2
Motor Coupling With Lead Screw	Aluminium Flexible Coupling
Nut Type Nut Material Plate Dimension Manufacturing Process	Single Plate with internal thread at two section Stainless Steel 100 X 180 mm Milling, Threading
Assembly Method	Bolting, welding

a. The vertical motion assembly uses two lead screw to move the gripper block up and down. One Lead screw is attached at the left side of the chassis using the bolting joint, whereas second at the right side using the same joint. The lead screw is attached to the chassis using the flexible coupling at the top and bottom position.
b. The flexible coupling is coupled with the motor shaft rigidly. The motor is fixed at the top position of the chassis lead screw support structure.
c. The flexible is used to avoid the misalignment and fluctuating forces between the motor shaft and the lead screw.
d. In this way the both the lead screw is fixed at the respective position as shown in the figure 5.
e. The nut is made with the help of stainless steel block with the milling operation in C shape. The upper and lower flange of C shape is used to drill holes followed by threading operation.
f. This nut is then passes through the lead screw to perform the lifting operation as follows.
g. When the left motor rotates in clockwise direction and the right motor with the same speed rotates in the anti-clockwise direction, the lifting force is developed and the gripper block is moved upwards.
h. When the right motor rotates in clockwise direction and the left motor with the same speed rotates in the anti-clockwise direction, the downward force is developed and the gripper block is moved downward direction. When the block reaches the top position near the motor 1 & 2 then the top limit switch is pressed then the motor is stopped. Whereas when the block is reached near the bottom position near the chassis the bottom limit switch is pressed and the motor is stopped. This limit switch worked as feedback signal to stop the motor in both the condition.
i. For vertical lift there are two vertical lead screw mounted where the block weight is divided along the two lead screw and the torque required by the single motor is also reduced.
j. The Lead screw is having self-locking property since the type of the thread is square.

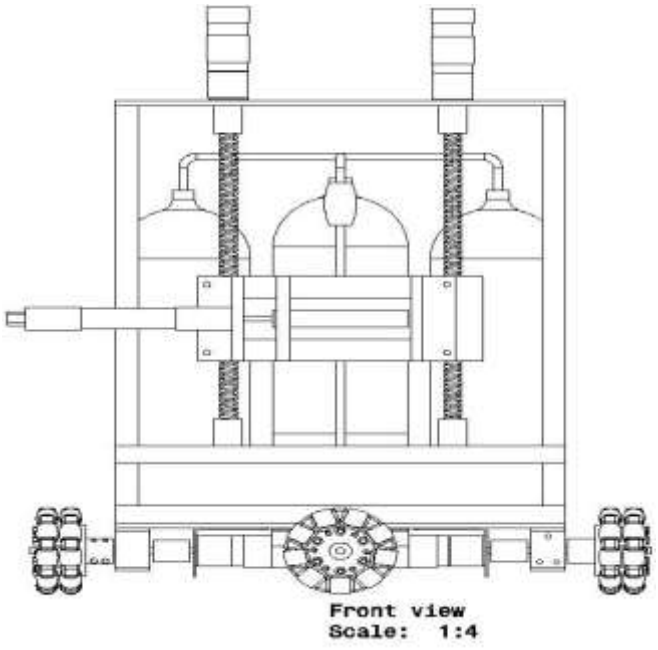

Figure 5: Vertical Motion Assembly

8. DESIGN OF PNEUMATIC GRIPPER

Pneumatic Piston	Round cylinders DSNU make festo
Mode of operation	Double-acting
Piston diameter	16mm
Theoretical force at 6 bar, advancing	23 to 295 N
Stroke	200 mm
Direction control valve	2/3 solenoid operated direction control valve
Number of piston	1
Number of DCV	1
Back Plate Stationary Arm Sliding arm	1 1 1
Manufacturing Process	Milling, drilling, threading, finishing
Assembly method	bolting

a. The gripper is manufactured using the four parts. First back plate of support plate which is acts as Nut for the lead screw. Second as stationary arms where these part is used to support the rest of the two parts. Third one is the sliding arm and fourth is the actuator.
b. The base of the mechanical gripper is made up of stainless steel rectangular section. The holes are drilled at the ends, as well as at the mid-section to clamp the stationary arm.
c. The stationary arm is the second part mounted between the sliding arm and the base support plate.
d. The stationary arm is manufactured into C section with the V slot made in between the two flanges of the C section. This slot is used to slide the sliding arm and to avoid the misalignment while sliding along the stationary arm.
e. The third section is sliding arm it is simple is structure with at the end with a V slot and with center drilled holes to clamp the actuator. The sliding arm is mounted in between the actuator and the stationary arm.
f. The actuator here used is pneumatic piston. The actuator is mounted at one of the flange of the stationary arm using the bolting.
g. Together all this four structural elements forms the pneumatic gripper.

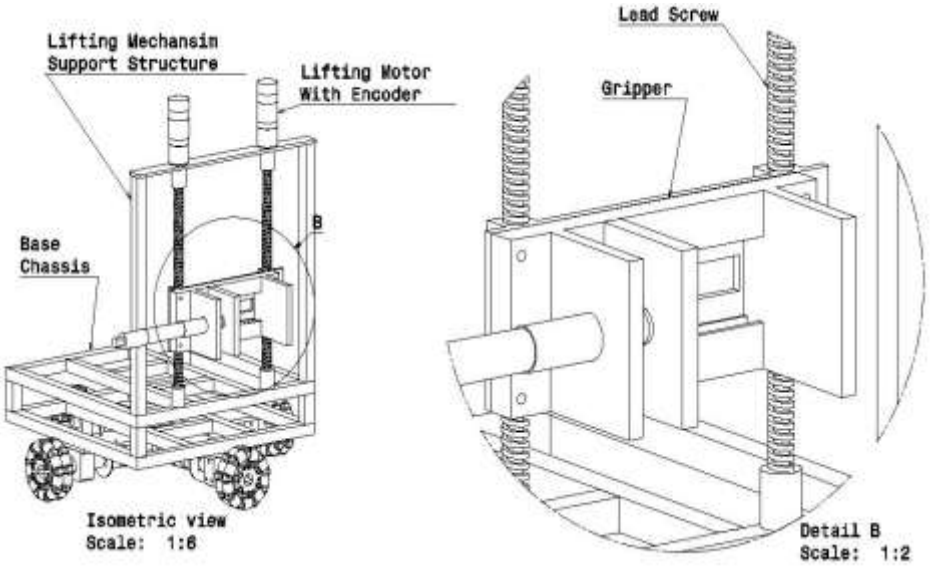

Figure 6: Detail Isometric View of Pneumatic Gripper

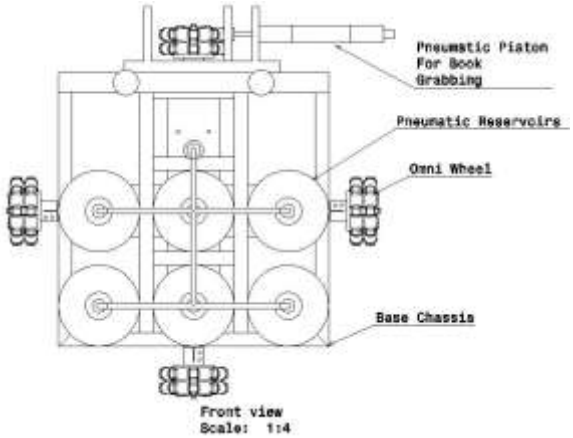

Figure 7: Pneumatic Gripper Assembly Top View

h. At the center of the stationary arm and the base plate there is a rectangular slot ploted in order to clamp the barcode reader. When the gripper clamps any book the reader reads the barcode pasted on the book. Which then uses as a feedback signals to know which book is been picked.
i. When the piston moves in forward direction, then the sliding arms comes closer to the other flange of the sationary arm, whereas, we can also say that the sliding arm moves away from the flange where the actuator is mounted on the stationary arm. This movement creates the compresive force on the book by which the book is been kept at stationay position while lifting and travelling.
j. When the sliding arm touches the limit of end-section then the limit switch is pressed and the robot comes to know that the book is grabbed. Same as when the arms touches the end section near the actuator holder the limit switch is pressed and the robot came to know the position of the arm.
k. To exert a specific amount of pressure there is pressure sensor (not shown in above diagram) is placed at the reservoir to detect the amount of pressure of the air by which piston exerted on the object to be grabbed. When the specific setted limit is reached the pressure control valve is used to bypass the pressure to atmosphere. This action is carried out to avoid any damage to the object.
l. As soon as the pressure limit is reached or the limit switches are pressed, the controller sends the led indication for user to understand the condition.

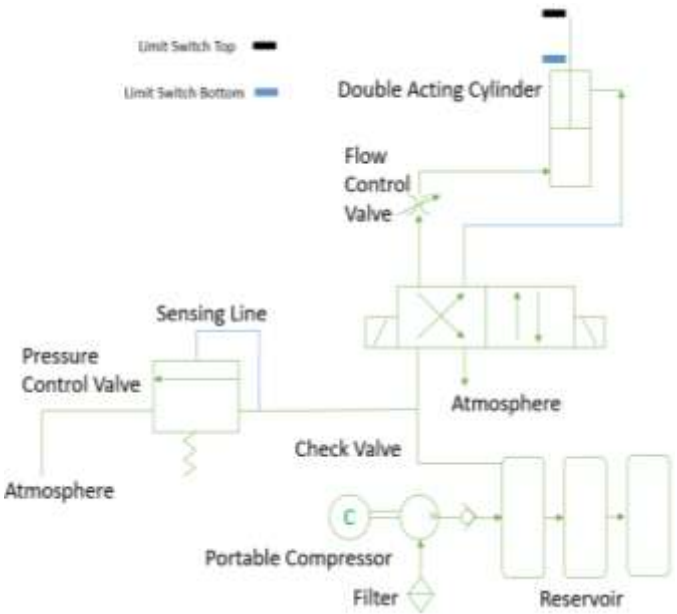

Figure 8: Pneumatic Gripper Circuit

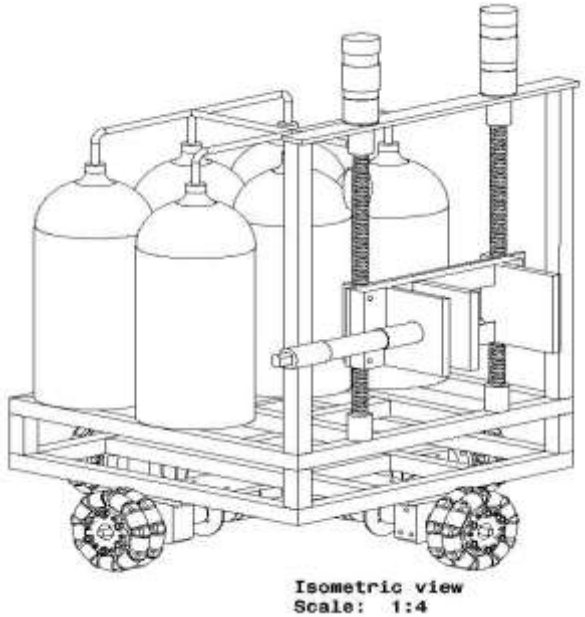

Figure 9: Complete Travelling Robot with Omni Directional Wheel

9. DISCUSSION

a. The Planetary geared motor is used as an actuator to carry out the vertical motion to lift the gripper.
b. Omni wheels are used to displace the robot in all the angles as considering the robot facing one direction placed at origin without any change in direction as follows: 45(diagonally), 90(Forward), 135(sideways), 180(backwards), 225(diagonally), 270(backwards), 315(diagonally), 360(sideways) degree angles.
c. The robot can take 360 degree rotation without changing the axis.
d. Robot is driven in autonomous mode using the line sensing array.
e. With the help of pneumatic gripper we could lift any kind of book.
f. For fast operation of lead screw mechanism we used double start lead screw.
g. Capacitive proximity sensor is used for detection of books and other objects along with limit switches for determining the limits of each mechanism.

REFERENCES

[1] Wing W. Y. Ng ; Yi-Song Qiao ; Li Lin ; Hai-Lan Ding ; Patrick P. K. Chan ; Daniel S. Yeung, "Intelligent book positioning for library using RFID and book spine matching", 2011 International Conference on Machine Learning and Cybernetics, 12 September 2011
[2] Yoshiyuki Nakano, Kanazawa (JP), Yusuke Kihara, Tokyo (JP), Katsuki Sakimoto, Yuuki (JP), Yoshiki Hayashi, Gifu-ken (JP), 'AUTOMATED LIBRARY SYSTEM WITH RETREVING AND RESPOSITING ROBOT', Patent Number US 6,535,790 B2, Mar. 18, 2003 (10) P.
[3] I. Ehrenberg, C. Floerkemeier, S. Sarma, "Inventory management with an RFID-equipped mobile robot", Proc. of the IEEE Int. Conf. on Automation Science and Engineering (CASE), 2007.
[4] S. Schneegans, P. Vorst, A. Zell, "Using RFID snapshots for mobile robot self-localization", Proc. of the European Conf. on Mobile Robots (ECMR), 2007.
[5] J. Thirumurugan, M. Vinoth, G. Kartheeswaran, M. Vishwanathan, "Line following robot for library inventory management system", INTERACT-2010
[6] Loh Poh Chuan, Ayob Johari, Mohd Helmy Abd Wahab, Danial Md. Nor, Nik Shahidah Afifi Md. Taujuddin, Mohd Erdi Ayob, "An RFID warehouse robot", 2007 International Conference on Intelligent and Advanced Systems, 24 October 2008
[7] Longfei Shangguan and Kyle Jamieson, Princeton University, University College London {longfeis, kylej}@cs.princeton.edu, "The Design and Implementation of a Mobile RFID Tag Sorting Robot"