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Library Management Robot
Design and Fabrication

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***Abstract*— Robots are used for various purposes in day-to-day life. With ever growing technology and competition there is a desire for doing work in less time, also considering economy in the equation. Keeping this into consideration this project aims at minimizing the efforts required to arrange books in a library. A library generally consists of thousands of books and there are two or three employees to arrange them. The Library Management Robot (LMR) will mitigate the problems by collecting the books from library counter and then arranging the books, one by one, into shelves.**

The LMR works on general principle of RFID, Line following and kinematics of robotic arm. The LMR will initially scan the RFID tag of a book and then find its shelf according to the data previously fed into it. Then it will travel to the shelf according to the path following the lines made on the floor of library. After reaching the shelf, LMR will pick the book and place it in the respective rack in the shelf. The same procedure will be repeated for every book.

The robot consists of a microprocessor (ATmega328), two motors for locomotion, four different motors for arm, RFID reader and proximity sensors for gathering surrounding information.

This project will definitely prove helpful for library enabling them to work efficiently and eliminating problem like misplacing of books.

***Keywords*— RFID; library management; robotic arm.**

I. INTRODUCTION

A. Introdution to Problem

- Difficult to search record when there is no computerized system, or if the records are large in number.[1]
- Placing books from the counter or reading table to the respective shelf.
- Due to increase in the number of shelves in the library it is difficult for a single person to remember such a large records.
- The cost reduction in the management of the library.
- Assisting the librarian to decrease efforts in managing the books in the library.

TABLE I. SPECIFICATIONS OF ROBOT

Parameter	Specifications
Model name of robot unit	Library Management Robot [L.M.R.]
Claw arm movement(*a)	(*a=) 125mm
Horizontal arm movement(*b)	(*b=) 100mm
Vertical arm movement(*c)	(*c=) 1200mm
Wrist rotating angle	±270°
Axis combination	X(1st axis)+Y(2nd axis)+Z(3rd axis)+T(4th axis)
Maximum payload	2kg
Composite speed	X(1st axis), Y(2nd axis) : 1000mm/s Z(3rd axis):2000mm/s T(4th axis):1500/s
Position repeatability	X(1st axis), Y(2nd axis), Z(3rd axis):±0.25cm T(4th axis):±0.18cm
Maximum allowable inertia moment around T-axis	0.078 kgm2
Position detection	Position encoder
Drive motor	DC servomotor for one joint + Johnson motors for two joints + Rectangular gearbox side shaft motors
Weight	Approx. 9.5 Kg

B. Description of Robot

The Library Management Robot helps to minimize the problem of library management by accurately identifying the place of the book according to the Dewey classification and placing the book in the right shelf. It identifies the unique identity of each book and searches for the place for that identity in the database feed to the robot [2].

The LMR has two main parts; base which has two motors, two degree of freedom, and column which has four motors, four degree of freedom. These motors are controlled by ATmega8 micro controller. This micro controller is programmed in such a way so that the whole functioning of the robot can be done by pressing a single button.

International Journal of Engineering Research & Technology (IJERT)
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Vol. 5 Issue 10, October-2016

II. COMPONENTS OF ROBOT

To achieve the objectives set, LMR is designed to have 4 + 2 that is 6 Degree of freedom. The arm consists of four degree of freedoms viz.

(i) For translating the X arm.
(ii) For translating the Y arm.
(iii) For lifting up the Cartesian box.
(iv) For rotating the Cartesian box along vertical axis.

A. Body Components

1) Chasis

The chassis for this robot is made up of mild steel sheet of 2 mm thickness. The sheet is bent into angles to provide strength. The chassis is of dimensions 18’’X12’’X5’’ (L X B X H). A step is provided on one side of chassis to allow more travel for the vertical arm.

Fig 1. Chassis

2) Castor Wheel

A **caster** (or **castor**) is a free to rotate, single, double, or compound wheel that is designed to be mounted to the bottom of a larger object (the "vehicle") so as to enable that object to be easily moved. They are available in various sizes, and are commonly made of rubber, plastic, nylon, aluminum, or stainless steel. The caster wheels used in this robot are made aluminum with a total height of 15mm.

Fig 2. Castor Wheel

3) Vertical Support Square Shaft

The vertical rod is made up of square section pipe of length 48’’. Weight/ Linear foot: 0.27750781 Kg. This material meets the following specs: ASTM A554 [3].

TABLE II. SQUARE PIPE SPECIFICATIONS

Chemistry Information: 304 Stainless Steel	
Element	*Percentage*
C	0.08 max
Cr	18 – 20
Fe	66.345 – 74
Mn	2 max
Ni	8 - 10.5
P	0.045 max
S	0.03 max
Si	1 max

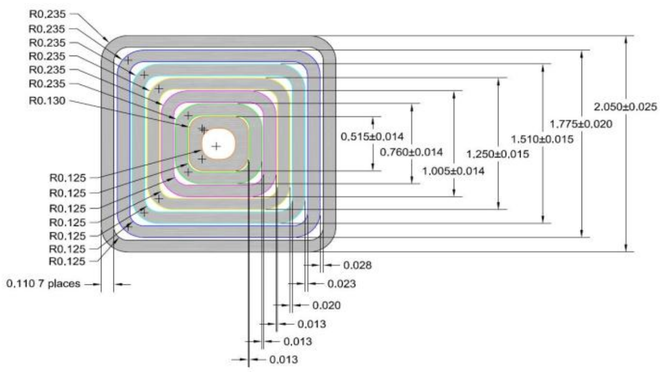

Fig 3. Pipe Dimensions

Fig 4. Square Pipe

4) Battery

The battery used here is a 12V and 7mAH dry lead-acid Battery. It find its application in UPS systems.

International Journal of Engineering Research & Technology (IJERT)
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Vol. 5 Issue 10, October-2016

Fig 5. Battery used

5) Control Box

The control box is the heart and brain of an actuator solution. It translates the signals from the control unit into perfectly controlled movement and adjustment of the actuators. The control box also links the various accessories connected to the system. It controls all the electrical components fitted in the robot. It encapsulates microcontroller as well as all the connections to each component.

6) Rectangular Gearbox Side shaft motor

It is a high torque DC motor that works on 12V. It runs at 200 rpm and torque provided by this motor is 35 kg-cm. The gear ratio employed by this motor is 350:1.

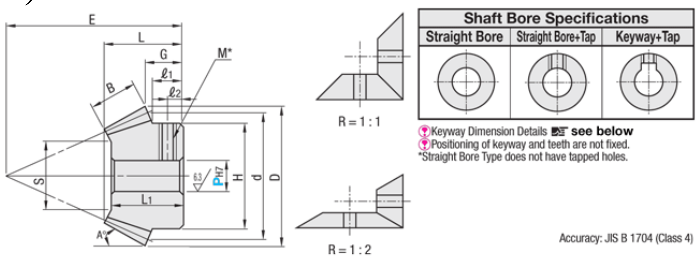
Fig 6. Side shaft DC Motor

7) Plastic Rack

The plastic rack used in this robot is of dimensions 22.86 cm X 1cm X 1cm (L X B X H). The module of the rack being 0.8.

Fig 7. Plastic Rack

8) Bevel Gears



(a)

(b)

Fig 8. (a) Bevel Gear Dimensions. (b) Bevel Gears Used.

9) Cartesian Box

a) Mechanical Components

1. X-Rod

It is used to provide a linear motion to the gripper. It provides a travel of 6cm which will enable the gripper to carry and place two books in one cycle.

2. Y-Rod

It is used to provide a linear travel of 15cm to the gripper. It will allow the gripper to go inside the shelf and come back.

3. Gripper

It consists of two moving members which come in contact with the book to pick it. It consists of a worm and two pinions to tighten and loosen the grip. When the motor turns clockwise, the gripper opens and vise-versa.

Fig 9. Worm and Worm gripper

4. Servo Motors

The servo circuitry is built right inside the motor unit and has a position able shaft, which usually is fitted with a gear (as shown below). The motor is controlled with an electric signal which determines the amount of movement of the shaft.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 10, October-2016

Fig 10. MG946R Servo Motor

5. Rollers

Plastic rollers with metal base are used to support various links and arms which move from one place to another.

Fig 11. Plastic Rollers

B. DC Motors

Two high torque DC motors of 150 rpm has been used in this robot.

Fig 12. DC Motor (High Torque)

III. SENSORS

A. White line sensor

As you can see in below figure, a line sensor is composed of a number cells and each cell is composed of a sender and a receiver. The particularity of this sender/receiver pair, is that it sends light that shall be reflected by the line to be detected but not by the eventually opaque background surrounding this line. Any sender/receiver pair that is able to make a difference between a line and the rest of ground (of a different color) can be used in a line sensor.

So the first aspect that affects the precision and the quality of a line sensor, is the number of cells. The second aspect to be considered when building a line sensor, is the cell spacing (or the distance between a cell and the other.)

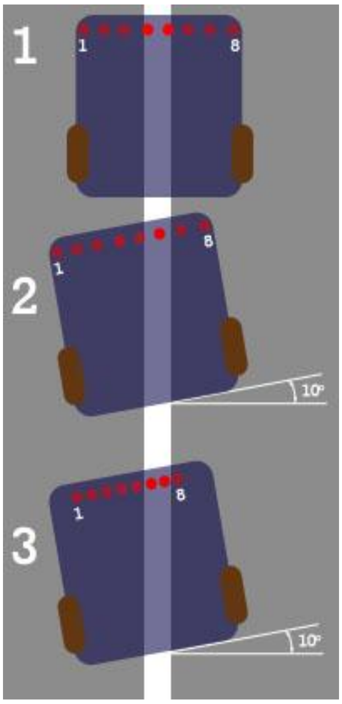


Fig. 13. Working of IR line follower

Fig 14. Digital white line sensor

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 10, October-2016

TABLE III. PIN CONFIGURATION OF WHITE LINE SENSOR

Pin No.	Connection
1	GND
2	VCC
3	Sensor1
4	Sensor2
5	Sensor3
6	Sensor4
7	Sensor5
8	NC
9	VCC
10	GND

B. RFID scanner

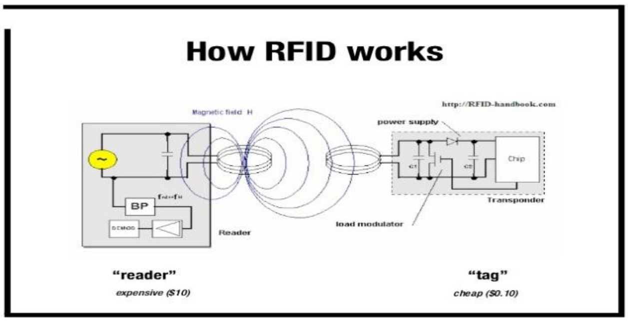


Fig15. Working of RFID Sensor

RFID is an acronym for “radio-frequency identification” and refers to a technology whereby digital data encoded in RFID tags or smart labels (defined below) are captured by a reader via radio waves. RFID is similar to barcoding in that data from a tag or label are captured by a device that stores the data in a database. RFID, however, has several advantages over systems that use barcode asset tracking software. The most notable is that RFID tag data can be read outside the line-of-sight, whereas barcodes must be aligned with an optical scanner.

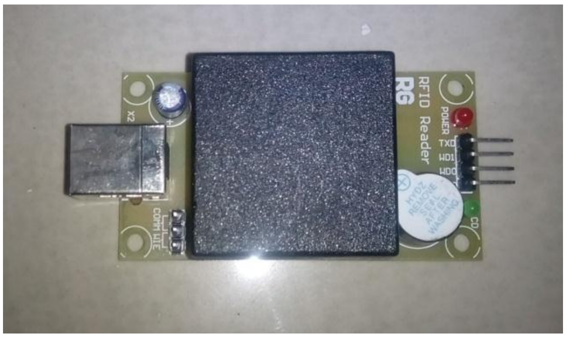


Fig 16. RFID scanner

RFID technology is employed in many industries to perform such tasks as:
– Inventory management
– Asset tracking
– Personnel tracking
– Controlling access to restricted areas
– ID badging
– Supply chain management
– Counterfeit prevention (e.g., in the pharmaceutical industry)

C. Position encoder

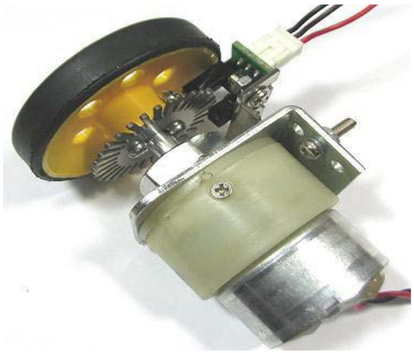


Fig 17. Position encoder

Position Encoder Kit used to measure speed of motor, find out distance travelled by robot etc.

In this assembly you will get Position Encoder with RA Mount with three pin Relimate connector, One Universal Wheel. This Wheel is made up of high strength nylon. Wheel has thickness of 10mm and diameter of 51.5mm.

TABLE IV. SPECIFICATIONS OF POSITION ENCODER

S. No.	Part	Specifications
1.	Position Encoder	Position Encoder with RA Mount Encoder resolution: 5.44mm / pulse.
2.	Encoder Metal Disk	Material: 1mm thick MS Disc Size: 39mm Diameter Mounting Hole Size: 3mm Diameter
3.	Universal Wheel	Diameter: 50mm Wheel thickness: 10mm. Hole: 6mm.
4.	Motor Mount	Material: 2mm thick MS steel. Size: Motor mounting side: Height 41mm, Width 38mm; Bracket mounting side: Height 21.5mm, Width 38mm. Hole for Motor mounting: 14mm diameter.

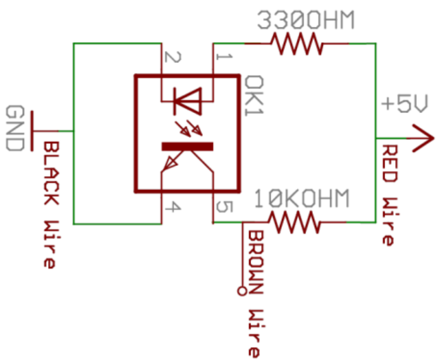


Fig 18. Schematic diagram of position encoder

International Journal of Engineering Research & Technology (IJERT)
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Vol. 5 Issue 10, October-2016

IV. CHIP CIRCUIT

A. *Motor driver L298N*

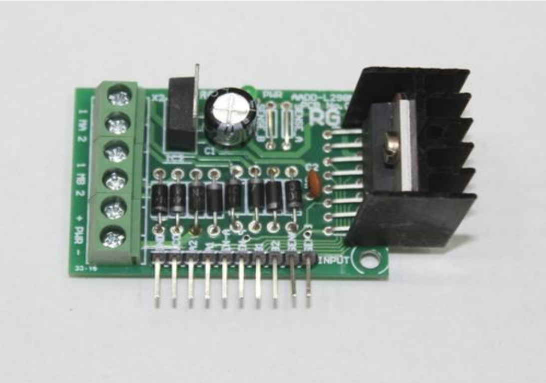

Fig. 19. L298N Motor Driver

Motor channels: 2
Maximum operating voltage: 46 V
Peak output current per channel: 2 A
Minimum logic voltage: 4.5 V
Maximum logic voltage: 7 V

B. *Motor driver L293D*

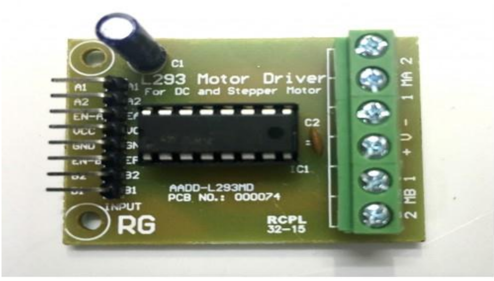

Fig. 20. L293D Motor Driver

Input Voltage: 4.5V – 36V
Max. Current: 600 mA for each motor
Can drive DC and Stepper Motors

C. *Arduino UNO ATmega328*

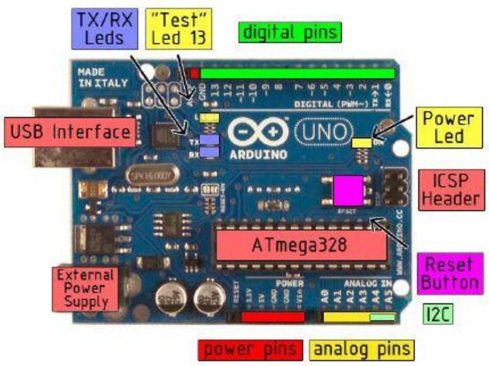

Fig. 21. Arduino UNO layout

TABLE V. ARDUNIO UNO SPECIFICATIONS

Name	Specifications
Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB of which 0.5 KB used by bootloader
SRAM	2 KB
EEPROM	1 KB
Clock Speed	16 MHz

V. DESIGN ANALYSIS WITH SPECIFICATION

A. *Requirements*

- To cover each of the six shelves of all the racks.
- To travel from the counter to the last rack following the white line attached close to the shelf for large free floor space.
- To fetch the shelf number of the book for placement.
- To not have any human interfere while in operation.
- To set an initialization button and kill switch for ease of operation.
-

B. *Limitations And Considerations*

- Minimum five DOF required to pick and place the book.
- Space limitation in making chassis of the robot.
- Two book carrying capacity which increases the gross weight.
- Power limitations due to unaffordable cost.
- Speed limitations due to unaffordable cost.
- Height limitation due to increase in height of center of gravity thus more power or more support hence increase in cost.

Fig. 22. Library for which designing of Robot is done.

C. *Design Of Different Parts*

1) *Design Of Chassis*

The distance between the two consecutive racks is 4ft. Thus the dimensions of the chassis is set to be 1 X 1.5 X 0 .5 cubic feet.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 10, October-2016

A step is provided at one side of the box of 1 X .5 square feet so that the Cartesian box can be travelled up to the last shelf.

The ground clearance is set to be 1.5cm to have low center of gravity and also to cover the bottom most shelf.

a)Design Of Vertical Rod

The height of the rod is calculated on the basis of the height of the top most shelf and the distance between two consecutive shelves, base height, cell height and base thickness.

$$h = b + 4 * c + 3 * t$$

Where,

h: Total height of vertical rod.
b: Height of base from the ground.
c: Height of each shelf.
t: Thickness of base of each shelf.

b) Design Of X-Rod

The length of the connecting rod between the vertical rod and the rod containing the claw (Y rod) is calculated according to the placement of the books in the temporary book kept on the robot.

The distance between the placements of the two books is found to be 6 cm for a general thickness of the book. Hence after the addition of the spaces used by roller supports, Y rod and Cartesian box, the length of X rod is set as 8”.

c) Design of Y-Rod

The length of the Y rod is calculated based on the shelf depth, distance of the robot from the shelf and the position of the vertical rod.

$$l = .5 * sd + c$$

Where,

l: Length of Y rod
sd: Depth of one shelf.
c: Clearance between the robot and shelf

d) Design Of Cartesian Box

The main and most complicated component of the robot is the Cartesian box. Its design is based on the dimensions of the roller support, design of X and Y rods, motor placements according to the rods[4].

VI. FABRICATION OF PARTS

A. 3D Printing

Some of the parts in the robot is manufactured using 3D printing technology such as jaws, spline hub and motor hub. The technology uses material known as ABS.

B. Chassis

The chassis with dimensions 1 X 1.5 X .5 ft^3 is made up of mild steel sheet of 2mm thickness. A step is also provided on one side which is by omitting the height of the front part of the robot of dimensions 0.5ftX 0.5 ft.

C. Vertical Column

A vertical column made of stainless steel square section rod of 26mm X 26mm and thickness 2mm. The height of the column with bearing housing on the top is 4ft.On the chassis end of the rod it is housed with the bevel gears with splined coupling of internal square section.

D. Cartesian Box

The Cartesian box is made of cuboidal shape, using mild steel sheet of 2mm thickness, of dimension 230mm X 80mm and thickness of 1mm. These four panels are bolstered to form a box by using 8 L-clamp. It encapsulates 3 motors for providing various motions to the arm. The Cartesian box is supported to the vertical column with the help of rollers from 3 sides and from pinion attached to remaining one side. X-rod is supported with 3 rollers at the base and 2 rollers from either sides. Also it supports a motor to drive Y-rod. The Y-rod is also supported with rollers for providing 2 D.O.F. to it.

VII. CALCULATIONS

A. Center Of Gravity Of The Robot

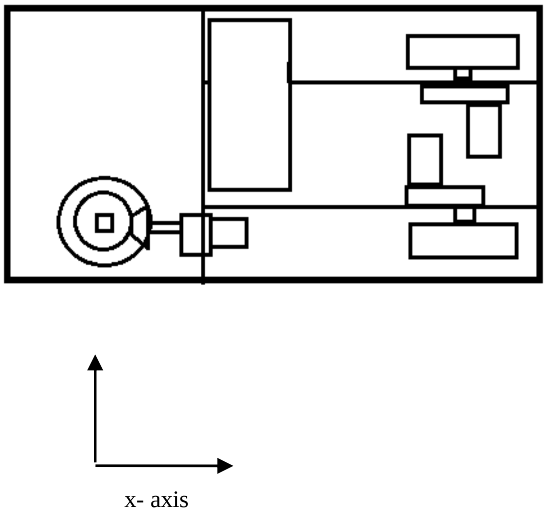

Fig. 23. Top View of Robot

Formula for calculation of C.G. is

$$C.G. = \frac{\sum(Mx\ R)}{\sum M}$$

Now, the mass of the components on robot are:

i.	Battery	:	1.5 Kg.
ii.	Drive motor	:	1.1 Kg.
iii.	Wheels	:	100 grams.
iv.	Bevel gear set	:	1.25 Kg.
v.	Johnson motors	:	280 grams.
vi.	Servo motor	:	55 grams.
vii.	Rack	:	48 grams.
viii.	Steel pipe	:	600 grams/feet

Nc ing the weights of each component and measuring the ive distances, the center of gravity of the robot is ob d by putting these values into the formula:

$\bar{x}$ = 22.42 cm

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 5 Issue 10, October-2016

$\bar{y}$ = 15.06 cm
$\bar{z}$ = 53.15 cm

B. Bending Moment Calculation

a) Bending Moment Without Book

i. Moment at claw (when claw is inside)

M_{claw} = 0.5x0.06x9.81
= 0.2943 N-m

ii. Moment at claw (when claw is outside)

M_{claw}= 0.5x0.19x9.81
= 0.931 N-m

iii. Moment of X-rod about point E

$M_{xc(e)}$= 0.66x9.81x0.21 + 0.221x9.81x0.105
= 3.636 N-m

$M_{xd(e)}$= 1.85 N-m

iv. Moment at Vertical Rod

M_{vr}=2.5x9.81x0.12 = 2.943 N-m

b) Bending Moment With Book

i. Moment at claw (when claw is inside)

M_{claw} = 2.5x0.06x9.81
= 1.4715 N-m

ii. Moment at claw (when claw is outside)

M_{claw}= 2.5x0.19x9.81
= 4.65 N-m

iii. Moment of X-rod about point E

$M_{xc(e)}$= 2.5x9.81x0.21
= 5.150 N-m

$M_{xd(e)}$= 4.1516 N-m

iv. Twisting Moment about point E when claw is at A

$T.M._{e(A)}$ = 2.5x9.81x0.06
= 1.4715 N-m

$T.M._{e(B)}$ =2.5x9.81x0.19
= 4.65 N-m

v. Moment at Vertical Rod

M_{vr}=2x9.81x0.24 + 2.5x9.81x0.12
= 7.6518 N-m

vi. Twisting moment at vertical rod

$T.M._{e(A)}$ = 2x9.81x0.24 N-m

VIII. WORKING & PERFORMANCE EVALUATION OF ROBOT

A. Working Of Robot

The robot is preprogrammed to do a defined task. It does every task in a predefined sequence, which is as follows:

STEP 1: Switching ON/OFF

The robot starts to work after being switched **ON** by the operator. This switch also acts as **kill switch** to stop the robot in case of malfunctioning.

STEP 2: Placing books on platform on robot

The operator can place upto two books on the platform of robot. The robot will successfully place these books to their shelves. The books should be placed such that the binded side of the book should face the claw of robot.

STEP 3: Scanning of book for shelf position

The robot then bring the claw to the leftmost book on the platform and then read the RFID tag of that book. Then by searching this tag ID in the database feed to the robot, it gets the shelf number and the path which the robot should travel in order to get to the destination shelf.

STEP 4: Traversing to the shelf

The robot then travels to the shelf where the book is to be kept. It does this by simply following the line on the floor and making decisions of turns by using the data in microcontroller.

STEP 5: Placement of Cartesian box

The height of the Cartesian box is adjusted by the vertical linear motion on the rack with the help of pinion, as shown in Fig. 24. After reaching the defined height, the gripper hand is moved forward and the book is inserted in the shelf.

STEP 6: Placing book

The book is then released from the gripper and the gripper hand is moved back and then lowered.

STEP 7: Scanning next book

The robot then scans next book by bringing the gripper near the book. The RFID of that book is then sent to the database to retrieve the shelf number and the path to travel to that shelf. Process shown in Fig. 25.

STEP 8: Placing second book

After successfully identifying the book shelf, the robot travels to the shelf and then places the book to the respective cell.

STEP 9: Returning to counter

After placing both the books in their shelves, the robot returns to the counter for beginning next Pick and Place Cycle.

Fig. 24. Manufactured Robot

International Journal of Engineering Research & Technology (IJERT)
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Vol. 5 Issue 10, October-2016

Fig. 25. Picking up book from platform

B. Performance Evaluation

The robot has been made as per designed to fulfill a particular need. Many problems have been faced in fabrication as well as implementation of the various motions. Thereafter the chassis and base has been prepared for properly balancing the weight of Cartesian box and traversing masses. Stability of the robot was a huge task. The overall center of gravity was much above the base.

The robot is capable of picking two books from the counter and placing them to the required shelves. The gripper can lift one book precisely to it's position. Also the robot could navigate itself towards the destination shelf and thus automatically places the book by reading it's radio frequency identity. It can carry two books at a time and can place one book at a time. Such robots in sufficient numbers can alleviate the work of placing books in robots.

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We would like to thank Professor Sanjay Jathar and Professor Rajguru, who had guided us throughout the work. They had motivated us to complete the work successfully.

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