UNIVERSITI TEKNOLOGI PETRONAS (UTP)

"Lego Librarian: Book Carrier"

By

Thulasi Palakrisnan 14404

A dissertation submitted to the
Information and Communication Technology Program
Universiti Teknologi PETRONAS
In partial fulfilment of the requirement for the
BACHELOR (Hons) OF TECHNOLOGY
(INFORMATION & COMMUNICATION TECHNOLOGY)

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CERTIFICATION OF APPROVAL

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Approved by,

_____
(PN. NORSHUHANI BT ZAMIN)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
Jan 2014

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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THULASI PALAKRISNAN

ABSTRACT

Artificial Intelligence is seen as a potential contributor in many industries and also in everyone's life. Transporting heavy loads is indeed difficult for humans to perform especially for elderly. This project focuses on solving the problem in the library of University Teknologi PETRONAS. An inexpensive, mobile and efficient robot is proposed to perform in this project. The robot is able to carry books and pass it to Book Sorter to place the books on the shelves. In this report, the functionalities of the robot have been discussed in detail. Moreover, the proposed design of the robot has also been attached. A study of load balancing, the speed of the robot surface type are conducted. The design has been tested with three parameters to obtain the optimum design of the robot. The design was further enhanced as it is necessary to meet the objectives of this project.

ACKNOWLEDGEMENTS

This research paper is made possible through the help and support from everyone, including: parents, lecturers, friends and people who are involved directly or indirectly in this project. Here, I would like to dedicate my acknowledgement of gratitude toward the following significant advisors and contributors.

Firstly, I would like to thank Pn. Norshuhani bt Zamin for her most support and encouragement as my supervisor. She kindly offered her help throughout the processes involved in this project. I would also like to thank her for her advices and opinions about my project in order to produce the best end product. She gave me an exposure in few exhibitions that helped me to shape my project in a better way.

I sincerely thank to my parents for their moral support and encouragement for me to produce the end product and to complete this project. The product of this project would not be possible without all of them.

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PROJECT BACKGROUND

1.0 Introduction

The positive development of Artificial Intelligence field nowadays has allowed us to invent robots that are intelligent enough to perform tasks that are almost impossible for humans to do. Robots can be said essential in industrial field as it has speed, efficiency, low maintenance, zero labor expenses and accurate. It has been proven that robots that are currently been used in many industries has increased the profit.

The International Federation of Robotics reported that global sales of industrial robots increased by 38 percent in 2011 over 2010 (World Robotics, 2012). The diagram below depicts the countries where robots are taking over in manufacturing industry:

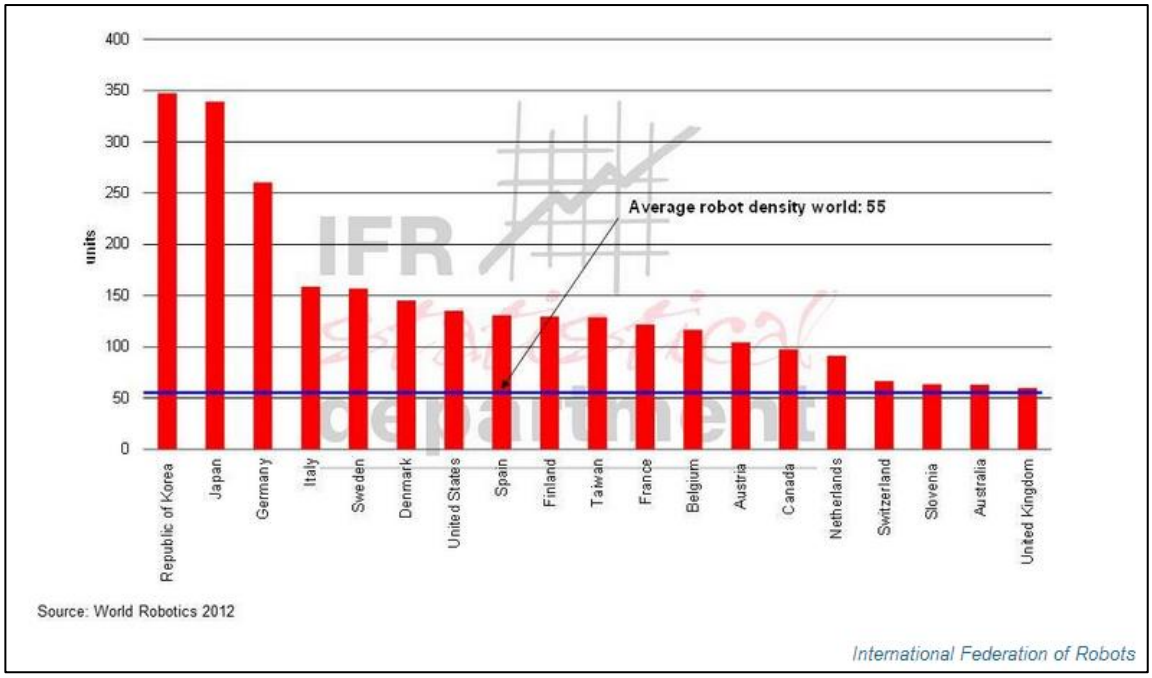


FIGURE 1.1: Number of multipurpose industrial robots per 10,000 employees 2011

The diagram shows the number of robots that are used in many countries and it is important to note that the average robot density is 55 units. Usage of robots can save up the wages given to employees and contribute to a company's income as well as improving the company's productivity.

The most difficult task to be carried out by human that may cause difficulties is lifting heavy loads.This is where robots can help humans to carry the loads efficiently and in a faster pace. Many places such as airports, manufacturing companies and even at home applies the duty of humans to carry or lift a load. Hence, this project will further discuss on an invention where a robot that will be able to carry certain amount of load.

1.1 Project Background

This project is a part of a system that is named as Lego Librarian. Lego Librarian is a mobile automated librarian system. This system comprises of two different robots which are Book Carrier and Book Sorter. This project is divided between two persons for their Final Year Project. I will be responsible in developing the Book Carrier while Siti Dzulaiqha will be developing the Book Sorter. The model for the Book Carrier is

derived from Lego Mindstorms kit. Since Lego Mindstorm kit is being provided in Universiti Teknologi PETRONAS, it assisted us in building those robots for our project.

The diagram below explains the system in more detail with some descriptions.

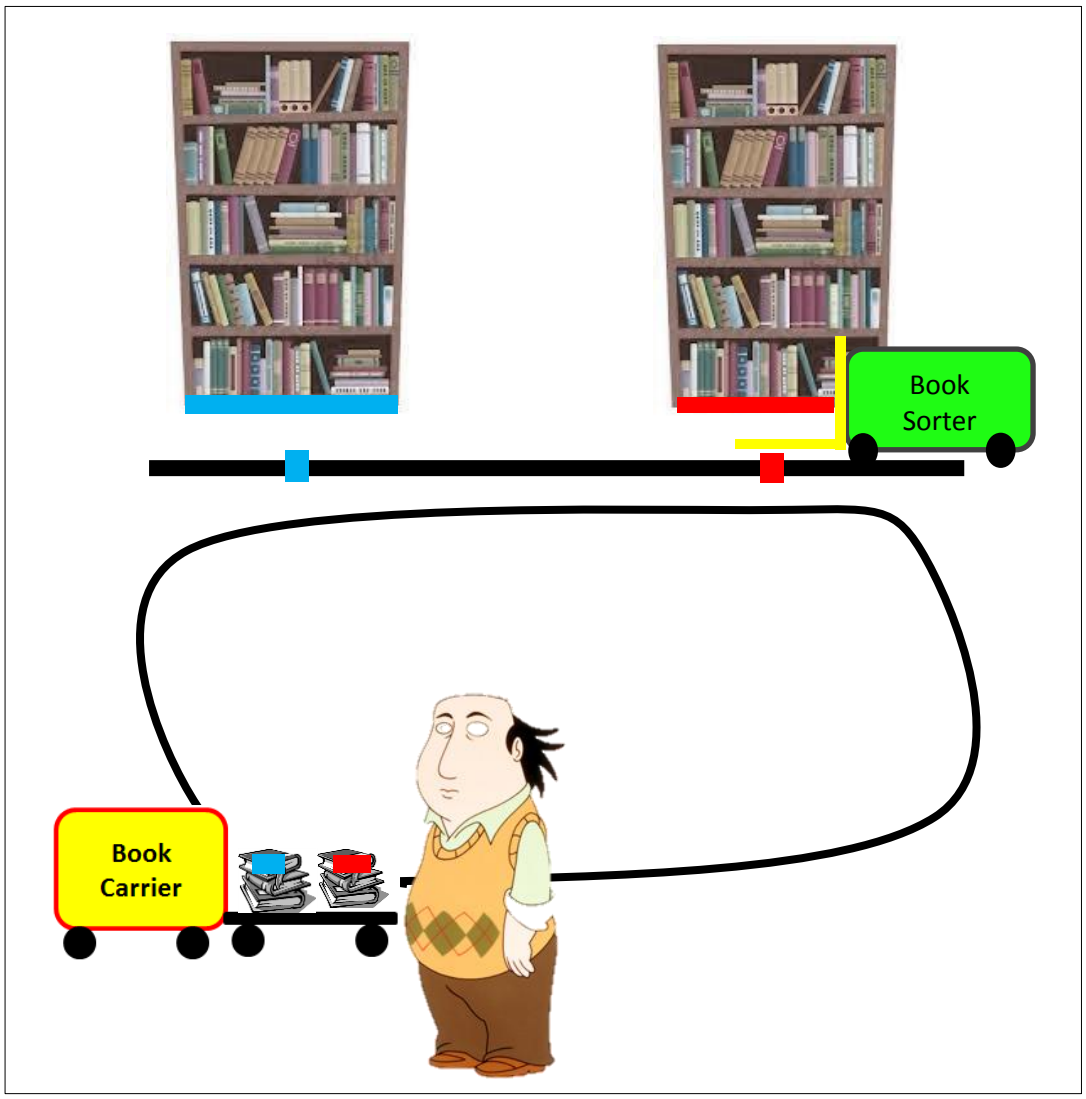


FIGURE 1.2: Lego Librarian

Since this system is only a simulation in a very small scale, the idea to make the system work is very simple. Two random colors are chosen to represent the book shelves for the small scale simulation: blue and red. Hence, the books that need to be arranged in the blue and red shelves will have a coloured sticker on them according to the color of the shelves in which they belong. In simple words, books with blue stickers on it belong to blue shelf whilst books with red stickers belong to the red shelf. When students return the books they have borrowed to the library's counter, the staff will place the books on Book Carrier. Then, the staff will give input to the Book Carrier directing to which shelf it should head. In this case, it is proposed to have two buttons (blue and red; according to the colour of the stickers on the book) on the robot. Assuming the input from the human is right, the robot will then proceed to the respective shelf following a line that directs the robot to the Book Sorter.

There will be colored strips placed in front of the shelf on the line that will be followed by the robot. These colored strips are tally with the color of the shelves. Once the robot starts moving, it will scan the strip's colors. If the strip's color is the same with the input color, it will stop moving indicating that it has reached the shelf where it has to pass the books to Book Sorter. Once reaching the shelf, it will send a signal to the Book Sorter for the Book Sorter to lift the books from the Book Carrier and place it at the shelf. The process will then repeat for the other shelves and the robot will then return back to the counter.

1.2 Problem Statement

The problem statements are divided into two parts which are objectives for the Lego Librarian (general) and objectives for Book Carrier (specific).

Problem Statement for Lego Librarian

- The manual process of transporting and sorting books is time-consuming and laborious.

Based on the case study done in Information Resource Centre (IRC) UTP, it was studied that the process of transporting the books from the main counter to the shelf as well as sorting the books takes a lot of time.

Problem Statement for Book Carrier

- Human carrying and transporting loads to different locations within the library is time-consuming and difficult to be accomplished in due time.

The books that are returned at the main counter at IRC, UTP will be placed in a trolley and it is claimed that the staff that are responsible to transport them to respective shelves face difficulties. This is because of the excessive weight of the books.

1.3 Objectives

The objectives are divided into two parts which are objectives for the Lego Librarian (general) and objectives for Book Carrier (specific).

The objectives for Lego Librarian

- To develop a mobile automated librarian system using a LEGO Mindstorm NXT 2.0 kit that is able to transport and sort books on the shelves to reduce the use of labour and time.

The objectives for Book Carrier

- To investigate load carrying and line following algorithm
- To develop a lab-scaled robot that is able to carry books from the collection counter to the shelves following line ability.
- To test the prototype with target users on lab-scaled mode.

1.4 Scopes of Study

Lego Librarian system is the collaboration of two robots: Book Carrier and Book Sorter. This research is focusing on the development of the Book Carrier prototype. Book Carrier focuses on few scopes of study in which it works till delivering the books to the right shelves while Book Sorter will be the one sort the books. Below is the list of Book Carrier's scopes of study:

1.4.1 Mobile Robots

A thorough study will be done on mobile robots and the method that is used to program the motion of the robot. Mobile robots can easily transport books to different locations and shelves.

1.4.2 Transporting Books

A thorough study will be done on robots that are able to transport loads from one destination to another. Since this project will be done using LEGO Mindstorms NXT 2.0 kit, the optimum weight that can be transported will best studied as well.

1.4.3 Line Following

The algorithm for the robot to follow a line will be studied and compared. The best algorithm will be implemented into this project. Line following is used to direct the robot to be on the right track and go to the right location.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

Artificial intelligence (AI) is the study and a branch of computer science devoted to the development of machines and software. AI researchers and textbooks define the field as “the study and design of intelligent agents", where intelligent agents refers to systems that understand and perceive their environment, and respond to maximize the chances of success. While John McCarthy also supports this definition, he explains that AI is the “science and engineering of making intelligent machines”(Rich, 2007).

On 11 May 1997, Deep Blue was the first computer chess-playing system to beat a reigning world chess champion (Rich, 2007). In 2005 Garry Kasparov, a Stanford robot won the DARPA Grand Challenge by driving autonomously for 131 miles along an unpredicted desert trail. Two years after that, a CMU team won the DARPA Urban Challenge when their vehicle autonomously navigated 55 miles in an urban environment while adhering to traffic hazards and all traffic laws. In February 2011, IBM's question answering system, Watson, defeated the two greatest Jeopardy champions, Brad Rutter and Ken Jennings, by a significant margin. The Kinect, which provides a 3D body motion interface for the Xbox 360, uses algorithms that emerged from lengthy AI research, as does the iPhone’s Siri system. This shows that the development of AI in the area of robot building has exhibited significant growth.

To apply the knowledge of artificial intelligence, building a robot is one of the most practical approaches of learning, and there are several suitable kits which can be used in education. One of them is the Lego Mindstorms kit. Lego Mindstorms is a series of programmable robotics kit from Lego. The core system consists of a control CPU, sensors and motors. Due to the flexibility of Lego Mindstorms kit, it is easy to quickly build a range of robots to perform many different and beneficial tasks.

The field of robotics is closely related to AI. This project applies the implementation o AI due to the vast opportunity of development in the world.A robot's "mind" must be programmed to understand its environment and to know when and how to execute the right functions to respond to changes in environment. For example, building a map of the environment and figuring out how to reach a goal or going from one point in space to another point, which may involve compliant motion. In order to satisfy the objectives of this project, the robot has to be programmed to be able withstand a certain amount of weight and follow the line. Industrial robots were first introduced in the production process around 1960 (Garcia,Jimenez,Santos & Armada , 2007). Many researches have been done in different areas of robotics such as kinematic calibration and motion planning.

Mobile load carrier robot is a very popular project in the field of Artificial Intelligence and Robotics. In the process of designing mobile load carrier, various literature reviews of past studies and researches need to be done in order to produce a good model. First, the evolution of a mobile robot is studied. Then, different types of robots that carry heavy loads are studied thoroughly.

2.1 Existing Automated Librarian Systems

A study regarding the design and implementation aspects of robotic 'Librarian' has been conducted by M. Prats, P.J. Sanz and A.P. del Pobil (2005) from Robotic Intelligence Laboratory of University Jaume I in Spain. It describes on the design and implementation aspects of robotic 'Librarian' that is developed to perform job in a library. The main idea of this paper is about the visual tracking and hybrid force control context. The proposed robotic librarian in this paper is subjected to be less than 100kg. It is the total weight of the controller, arm and the uninterruptible power supply (UPS) system. This detailed calculation is made for the mobile robot to carry with no problems at all. Apart from that, the robot is developed to have sonar sensors and bumper in purpose of navigation and collision detection.

The arm of the robot is equipped with a gripper, stereo camera, force sensor and infrared distance sensors. The stereo camera is responsible for locating the books on the shelf while the gripper is used for grasping purpose. In order to measure contact forces and torques, a six degree-of-freedom force sensor has to be located in between the gripper and the robot end-effector. It is also stated that the arm is endowed with some infrared distance sensors for noticing the obstacles and collision avoidance M. Prats, P.J. Sanz and A.P. del Pobil (2005). An inside computer situated in the mobile robot that comprises of AMD Athlon XP running at 1.6GHz, 512Mb of RAM and Linux operating system is in charge of controlling the system. It enables a communication between the mobile robot microcontroller via the serial port as well as the force sensor and manipulator through 2 different PCI cards and gripper through the input/output (expansion) board with the stereo camera that is using IEEE1394 interface.

According to Sanz and Pobil (2005), the vision module is important in distinguishing the details of the book which acts as books tag reader in locating the right shelves. This paper emphasized on a unique architecture of vision module that allows the camera to read the tag while moving. By having an open source optical character recognition (OCR) such as GOCR and joined with a new technology like computer vision libraries, it helps to improve the quality of recognition module making it more efficient. This information will be passed to the OCR module for them to read the identification codes. After that, the searching algorithm will decide the path to move the manipulator based on the readings. This is done for the purpose of finding the books.

As soon as the OCR module finds the book, the grasping module will get the position image of the book which is made to order the robot to reach the book and for the arm to grasp it. In order to complete this task, Sanz and Pobil (2005) implemented a closed loop referring to the visual and force details that will lead to a more efficient and fast method. Therefore, it is needed to blend force and visual known as hybrid control law. It continues by enabling the two degrees of freedom control which is forcing one to be in perpendicular and the other one in parallel direction to the books. An image based visual is used in parallel direction by using the book's edges as graphic features while the perpendicular direction is filled up by force in making contact with the book. Whenever

it is contacted, the force sensing is turned on by switching with the control law. One more degree of freedom is automatically being used in case of the book is tilted.

In 2012, Appiah-Berko , Dykhuis, Helmus, and Maduagwu developed "The Librarian" to arrange books on the bookshelves. They created a program in the form of a Microsoft Excel spreadsheet that was able to compare the order of the books scanned and highlighted any books that were not in the right order.

Line Following robot was created for library inventory management system by Thirumurugan, Kartheeswaran, Vinoth, and Vishwanathan, M. (2010) to simplify the job of arranging the books by library staff. Basically, this robot has a barcode reader that reads the barcode from the books that are arranged in a vertical manner and compares the decoded barcode data with the search input. Later, the robot gives the location of the book to the librarian once it reaches the book which is to be found out. Table 2.1 summarizes the existing librarian systems.

TABLE 2.1: Existing Librarian Systems

System / **Properties**	**Library Inventory System**	**Books Shelving System**	**Librarian Robot System**
Goal	To search for the misplaced books	To search and sort the misplaced books	To arrange books on the bookshelves
Scanning Mechanism	Barcode reader	RFID reader	Floor-RFID-tag reader
Commercialization Availability	No	No	No

2.2 Mobile Robots

Mobile robots are known as robots that can move in any given environment. Figure 2.1 and Figure 2.2 are examples of mobile robots. Garcia et al.(2007) agree that mobile robots consist of a platform moved by locomotive elements and the elements depend on the environment in which the robot will operate. There are a lot of strategies that have been introduced for motion planning for robots. However, many researchers have come into a conclusion that there are problems that exist in controlling the mobile robots. Previously, Shibata, Fukuda & Tanie (1993) and Gat (1992) mentioned that controlling mobile robots is hard for many reasons such as finding a collision free path and sensors that could not provide accurate information.

Motion planning is done based on algorithms such as Genetic Algorithm in hierarchical intelligent control. The best solution that was agreed by Garcia et al.(2007) is by having the operations in a control loop. This concept is applicable in this project in which the whole process will be done in a loop to sustain the level of performance of the robot.

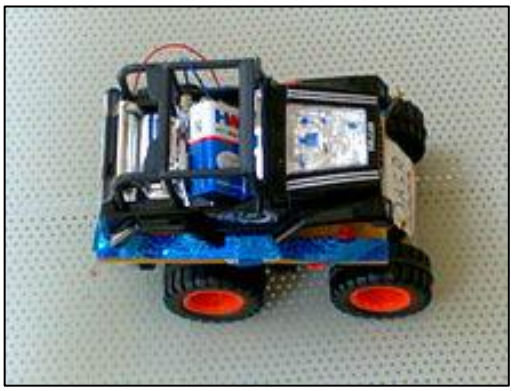


FIGURE 2.1: A mobile robot

Source: http://en.wikipedia.org/wiki/Mobile_robot

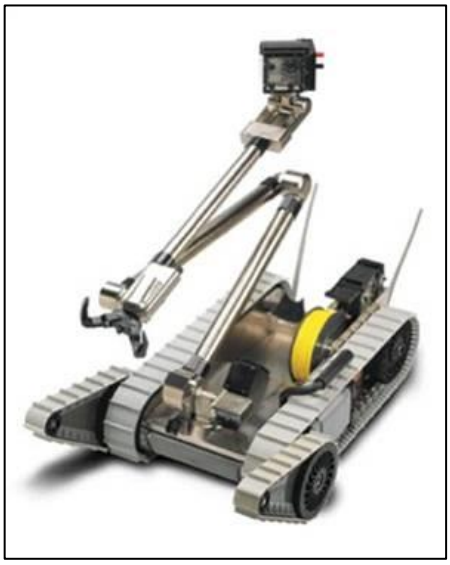


FIGURE 2.2: A Mobile Robot

Source: http://www.shifz.com/2006/05/scoobie-doo-tactical-mobile-robot.html

2.3 Load Carrying Robots

The task of carrying some load such as bags, books, groceries and many more is inevitable in human daily life. Most of the time, it is very difficult for human to carry the load when it is too heavy particularly for the elderly people. According to Farivar and Naeni (2012), there are many negative impacts that can be caused by manual handling of loads such as:

i. Cumulative disorders due to gradual and cumulative deterioration of the musculoskeletal system.
ii. Back pain which is the major work-related health complaint

As for a study on a survey of ergonomic parameters of shoppers, Farivar and Naeni (2012) mentioned that elderly people and women are most likely unable to carry heavy

loads. Hence, shoppers are introduced as a solution for this problem. Besides shopping sector, heavy load is also a problem in working sectors. In airports, it is a major problem for many people in transferring heavy luggage from one place to another.

In order to solve this problem, many robots have been developed and introduced to be used in many sectors to reduce humans' burden. Ikeura, Moriguchi & Mizutani (2002) mentioned that there should always be a communication or an interaction between human and robot. This will be helpful when robots are implemented to help humans in carrying out their daily tasks. In the last few years, many researches have been done on the area of load sharing between human and a robot. This defines that the robots that are being tested carry the load partially. Ikeura et al. (2002) and Kosuge, Sato & Kazamura (2000), have been control methods in order for the robot to cooperate with human and follow the human.

On a similar note, Dean & Fleming (2002) mentioned that mobility is difficult to control in a system simulation when load is present. The speed of a mobile robot decreases if the load that is being lifted by the robot is heavier. Hence, the optimum weight of the load must be determined in order to maintain the speed of the robot.

The experiment done by Ikeura et al.(2002) is limited to one degree freedom in the horizontal plane which clearly proves that the possibility of the load sharing between human and robot on an inclined plane is not being tested thoroughly. Having this as a base, this project will further study on the mobility of robot with load on an inclined plane.

Based on all these studies, a robot that needs to carry heavy loads needs a sufficient amount of batteries and also motors. Lego Mindstorm Kit provides the user with the easiest way of building a robot and has the ability to withstand certain amount. Thus, it is expected that this project will be successfull.

2.4 Maneuvering Algorithms

This project uses sensors to carry out one of its stimulation which is following a line and and sensing the right color strips that represents the shelves' color. Based on several studies, it is the best to use the light sensor of LEGO Mindstorm NXT 2.0 for line following. Color sensor is used to detect the color strips that are placed on the line to stop and deliver those books.

2.4.1 Line Following

Line following is a method that is used to control the movement and path selection of the robot. Skaff (2003) remarked that the capability of following line is useful for guiding autonomous platforms such as unmanned vehicles. A robot that detects the line will follow wherever the line directs it to go. Most of the robots use visual inputs to track the line. It was claimed by Dupuis and Parizeau (2006) that robots that detecting lines using visual inputs are not very effective in performance. The image processing in the robot is not very efficient causing most of the robots to not follow the line properly. Besides that, Skaff (2003) also claimed that sensors based capability need to be extended.

The line following robot that was created for library inventory management system by Thirumurugan, Kartheeswaran, Vinoth, and Vishwanathan, M. (2010) is also a good example on line following method that is intended to be used in this project. The technical process that is done in this project is shown in Figure 2.3.

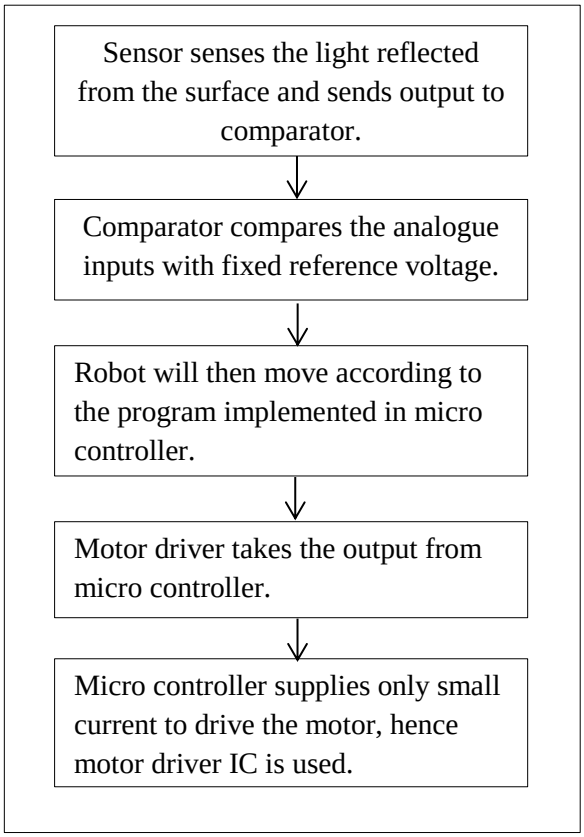


FIGURE 2.3: Robot Movement in Library Inventory System

In LEGO Mindstorm NXT 2.0 kit, light sensor is given for the robots to perform line following intelligence. In this project, this sensor is used for the Book Carrier. Light sensor will check for the brightness of line. It can be programmed in a way that the sensor follows only a black line.

2.5 Investigation of the Manual System at UTP Library

A study has been conducted regarding the manual system conducted in IRC UTP with Mr.Faris Syahmi , who is one of the staff that is working in IRC UTP. Firstly, he mentioned that there are two types of works being done in the process of books arranging.

- Sorting: Placing books from the trolley at the rack they belong to. The books are placed at the first level of the rack.
- Shelving: Placing the sorted books according to shelves.

He is in charge of sorting the books to the respective shelves. Based on the interview, there are 5 trolleys initially placed at the books receiving counter. One trolley represents each level. In one trolley, 100 books are placed. Hence, once the staff at the counter will receive books from students, they will place the books on the trolleys according to which level it belongs to. The staff that is responsible for each level/trolley will then bring the books to the level and place the books on the respective shelves. Another staff will be responsible in shelving those books.

There are two different shifts for the staff to sort the books which are:

- 8.30 am – 10.30 am
- 1.00 pm – 3.00 pm

Mr. Syahmi claimed that the process of pushing the trolley to the racks and also sorting the books takes a long time. It might take up to 1 hour for those who are new at work. The diagram below depicts the time and the number of labors for the process done in IRC UTP.

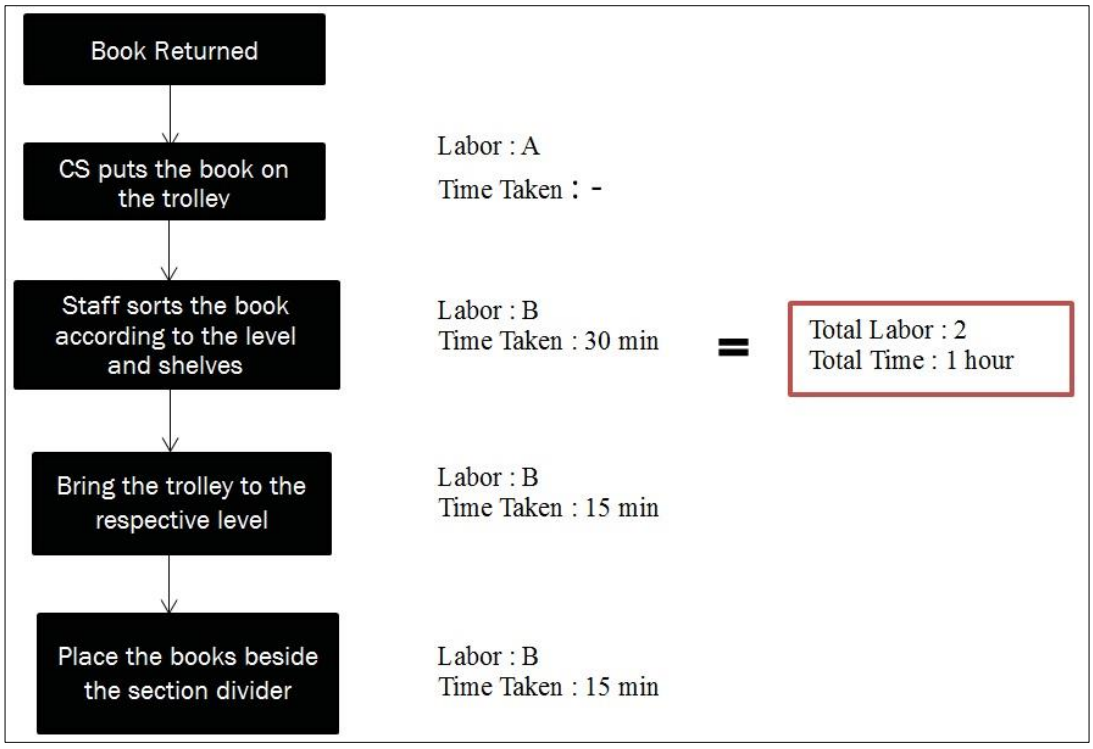


FIGURE 2.4: Manual Process in IRC UTP

Furthermore, a discussion with Mr. Faris (Personal Interview, 2013, November 15) about the factors that affect the effectiveness of the manual system that is being practiced in IRC UTP has been conducted. According to Mr. Faris, the main factor is gender difference. The female staffs take a longer time than men staffs to push the trolley to respective racks. In addition, the weight of the trolley also affects the process. Since one trolley is filled with 100 books, it is too heavy that it causes difficulties for the staffs to push the trolley to the lift and then to the respective racks.

There are also occurrences where the staffs tend to be lazy at work due to the heaviness, and the sorting processes are postponed. This causes for the whole process to be delayed and completed in days.

Lego Librarian is proposed to reduce the number of labors and also the time taken to complete the process of transporting the books to the racks and sorting them. The time

taken by Lego Librarian's Book Carrier and Book Sorter will be measured and compared in FYP II.

CHAPTER 3

METHODOLOGY

3.0 Introduction

The achievements of the objectives of this project within the allocated time are crucial. Therefore a proper planning and scheduling is needed to complete the tasks within the timeframe. A good planning and scheduling will greatly influence the outcome of this project. In this chapter the research methodology is discussed. The process flow and the tools required will also be discussed.

3.1 Development Methodology

The development methodology that is used in this project is Throwaway Prototyping. Figure 3.1 depicts the development methodology.

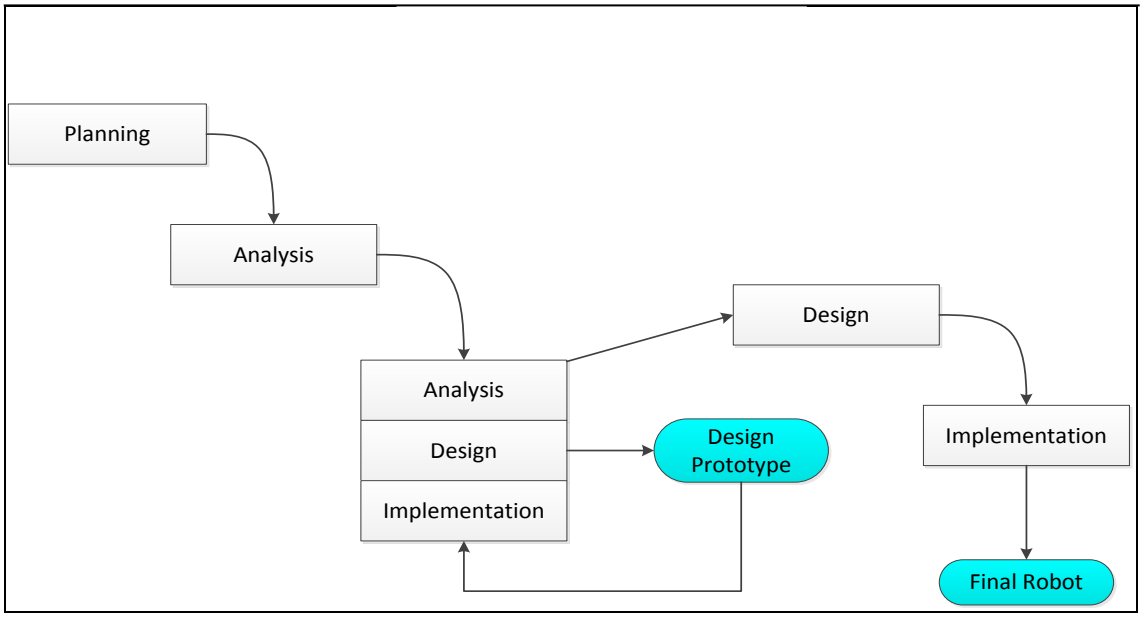


FIGURE 3.1: Throwaway Prototype Methodology Diagram

As seen in Figure 3.1, the first step of ‘Throwaway Prototyping’ methodology is the planning stage. It is conducted to discuss different ideas for the system concept. This project has evaluated different sample robot models that could be built using the available Lego Mindstorms components, and assessed the possible intelligence attributes we could program into them. A robot model was selected and developed as part of execution step in the methodology. The model is then analyzed thoroughly if the sensors can be built in correctly according to the functions. The project then moved to design and implementation phase where ‘Trailer Pull’ model was selected to be built.

3.2 Research Methodology

In order to achieve the main objectives of this project, the correct procedures and processes have to be followed and accomplished. For the first objective which is to investigate load carrying and line following algorithms, a thorough consideration and justification need to be conducted because the sensor used in the robot must be placed in a relatively low position to detect the line.

Next is to develop a lab scaled robot that is able to carry books from the collection counter to the shelves following ability. The affecting parameters such as the speed of the robot are observed to propose the best design. This is true because the load will affect the speed of the robot, in which an optimum weight of the load should be determined in order to maintain the speed of the robot.

Following that, the proposed design model is simulated using finite element software which is readily available in the LEGO Mindstorm Kit. The result is analyzed further to discuss on its performance and efficiency. The design is compared against three parameters which are weight of the robot, speed of the robot and the surface type.

3.3 Development Process Flow

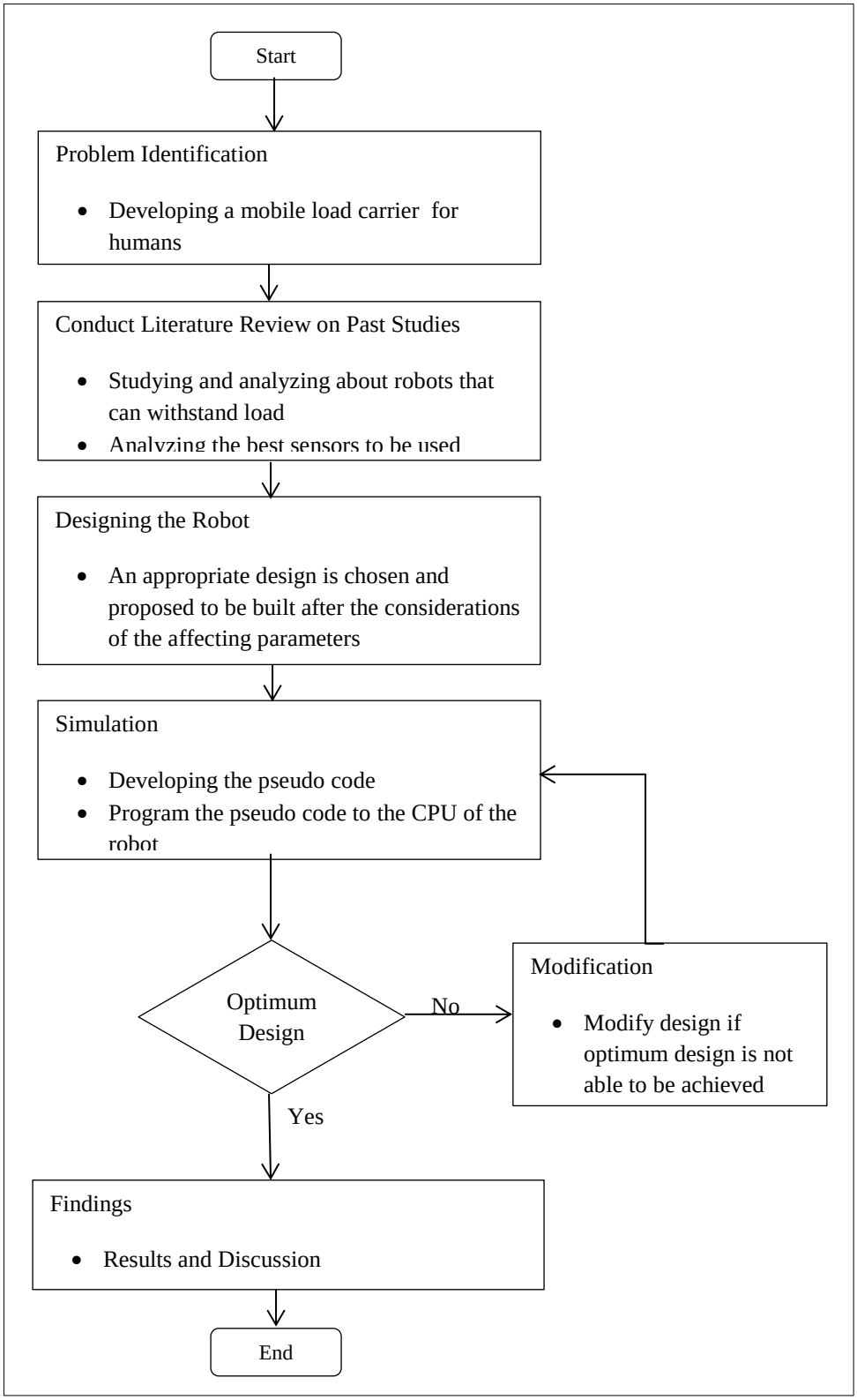


FIGURE 3.2: Process Flow of Project Execution

3.4 Design of the Robot

Figures 3.3, 3.4 and 3.5 below show the initial design of the robot that is developed later using Lego Mindstroms Kit.

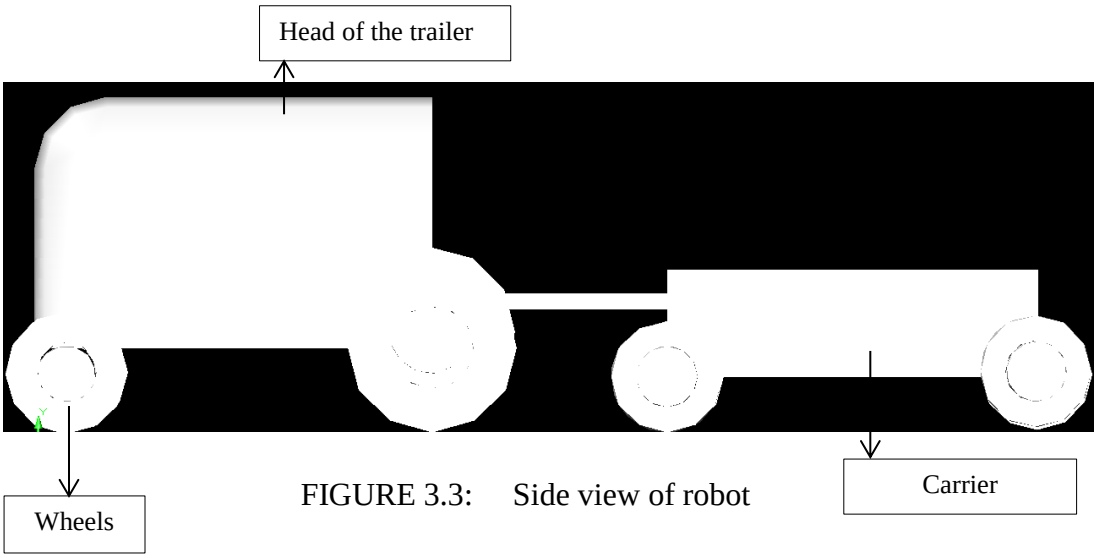


FIGURE 3.3: Side view of robot

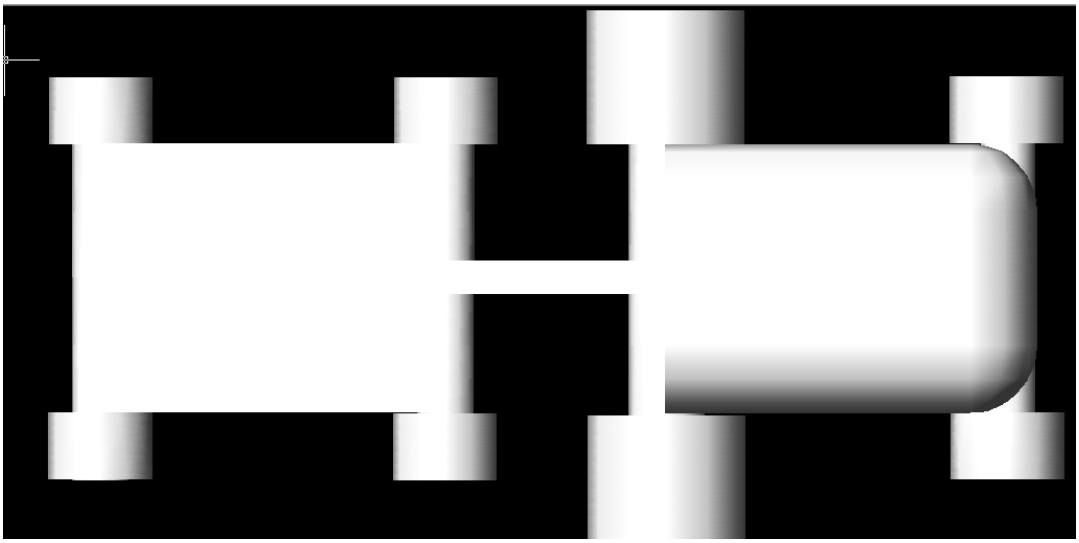


FIGURE 3.4: Top view of robot

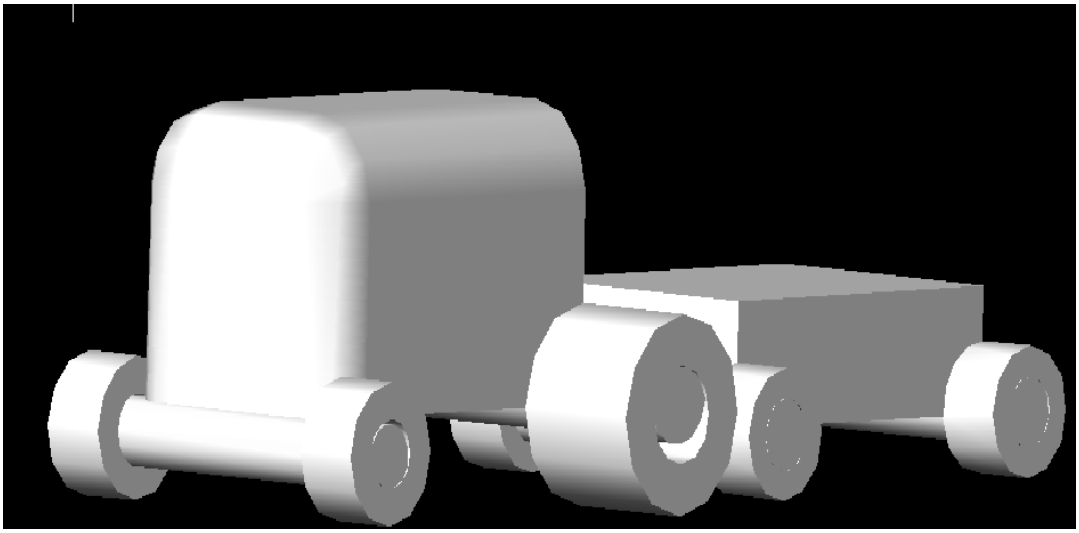


FIGURE 3.5: 3D view of robot

This design is chosen in such a way that the carrier is placed at the back to carry the books. The CPU is placed in front together with the sensors near the wheels.

3.5 Maneuvering Algorithm

This prototype is a robot designed to embrace the appearance of a trailer. It is built using components provided by the Lego Mindstorms NXT 2.0 robot series as a modified prototype.

To simulate the behavior of moving forward, following a line, an algorithm is created to instruct the robot's behavior based on its current condition and the environment surrounding it. The sensors that are involved will be placed on the robot. Figure 3.6 shows the pseudo code for the robot.

```
1.0 If(strip color== color input from human)

        2.1.1 Stop
        2.1.3 Wait for respond from Book Sorter (to
        indicate the job is done)
        2.1.4 Move forward
    2.2 Else
      2.2.1 If (strip color == yellow)
      2.2.2 Stop
      2.2.3 Else
            2.2.3.1 Back to 1

1.0 Go to 1
```

FIGURE 3.6: Pseudocode

The algorithm is designed so that at each step, the robot will follow the line till the book shelf. The robot will keep checking for the color strip on the floor with the input color by the human. If it is the same, then the robot will stop and call out for the Book Sorter to lift the books and place it on the shelf. If it is not the same color, it will continue to scan for the color of the strip. Once it sense yellow strip on the floor, it will stop moving and that is the sign of it finally reached the counter again.

3.6 Activity Diagram

The diagram below shows how the book carrier supposed to function.

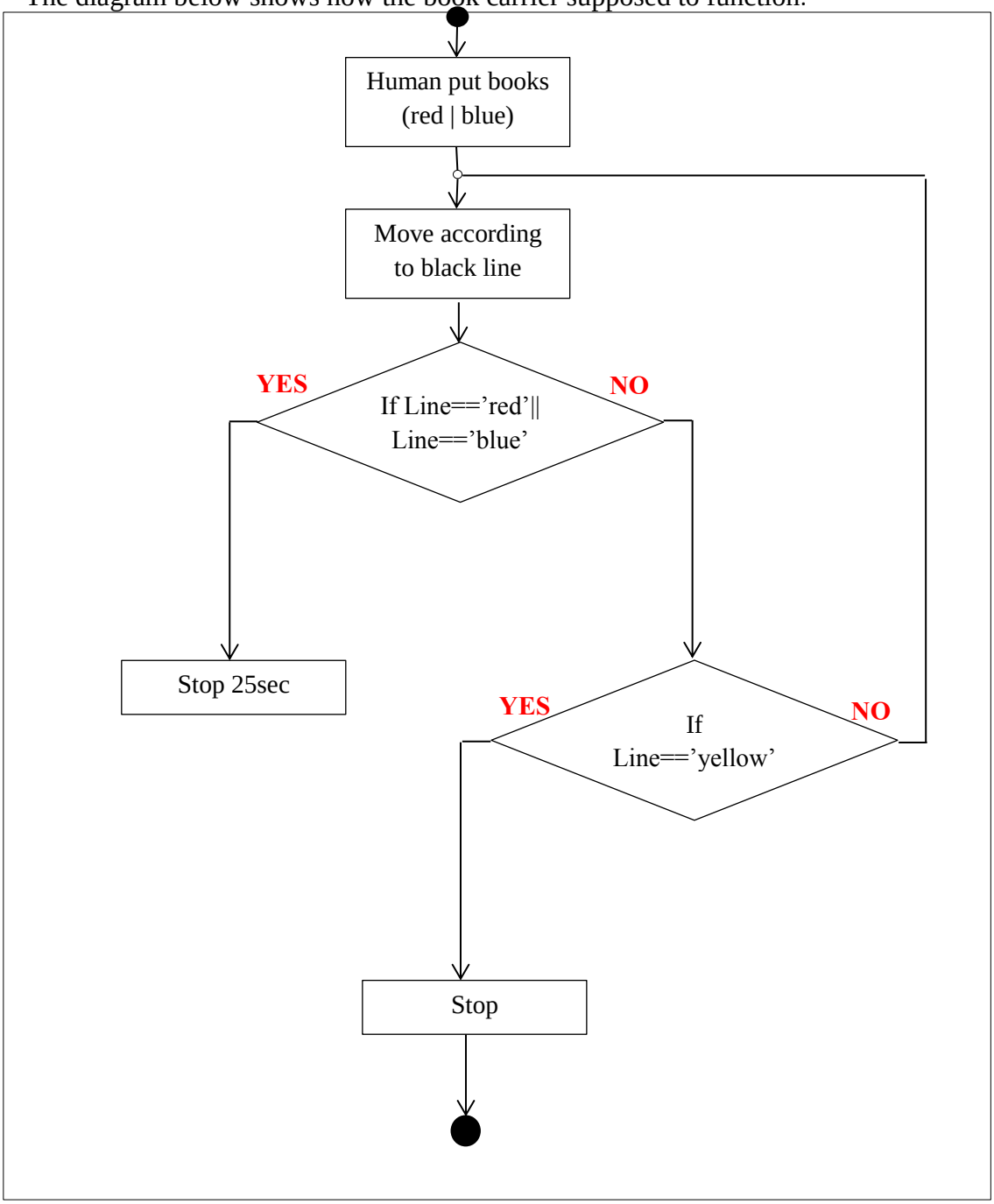


FIGURE 3.7: Activity Diagram

3.7 Gantt Chart

Table 3.1 is the Gantt Chart that is used to fulfill FYP I and FYP II requirements completely.

TABLE 3.1: Gantt Chart

Project Tasks	**Month**								
	Sep	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**
Project Title Selection									
Planning and Research Phase • Literature Review									
Design and Simulation Phase • Proposing design, simulation and analyzing									
Optimization of Design Phase • Modification to achieve optimization									
Presentation Phase • Progress Report • Pre SEDEX • Draft Report • Dissertation									

• Technical Paper • Oral Presentation • Project Dissertation									

3.8 Key Milestones

The Key Milestones had been achieved accordingly throughout FYP I and FYP II time frame.

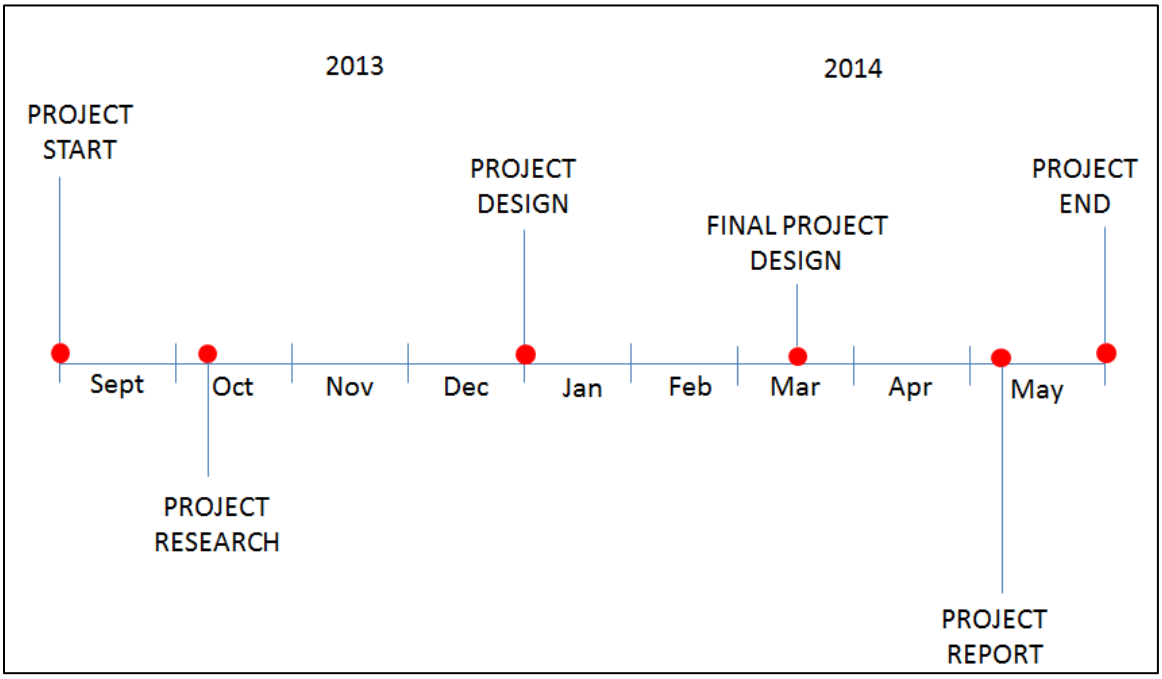


FIGURE 3.8: Key Milestones

3.9 Tools

Table 3.2 shows the tools that are used to complete this project.

TABLE 3.2: Tools Required

No	Tools	Function
1	Lego Mindstorm Kit	To build the robot and program the pseudo code
2	Autocad	To design/sketch the robot before building
3	Microsoft Excel	To tabulate results and findings
4	Microsoft Word	To document the project work

CHAPTER 4

RESULTS AND DISCUSSION

4.0 Introduction

In FYP I and FYP II, several progresses have been achieved. In this project, more experiments and improvements will be done to those progresses to achieve the objectives successfully. This section describes the achieved progresses, the experiments and the improvements done to them.

4.1 Robot Design

It took one day to build the robot according to the proposed design. As an improvement to the progress report, sensors were attached to the first prototypes that were built. Color sensor to follow the line as well as to detect the shelves added to the robot. Figures 4.1, 4.2, 4.3, 4.4, 4.5 and 4.6 show the first prototype and the final prototype of Book Carrier.

4.1.1 Initial Design of Robot

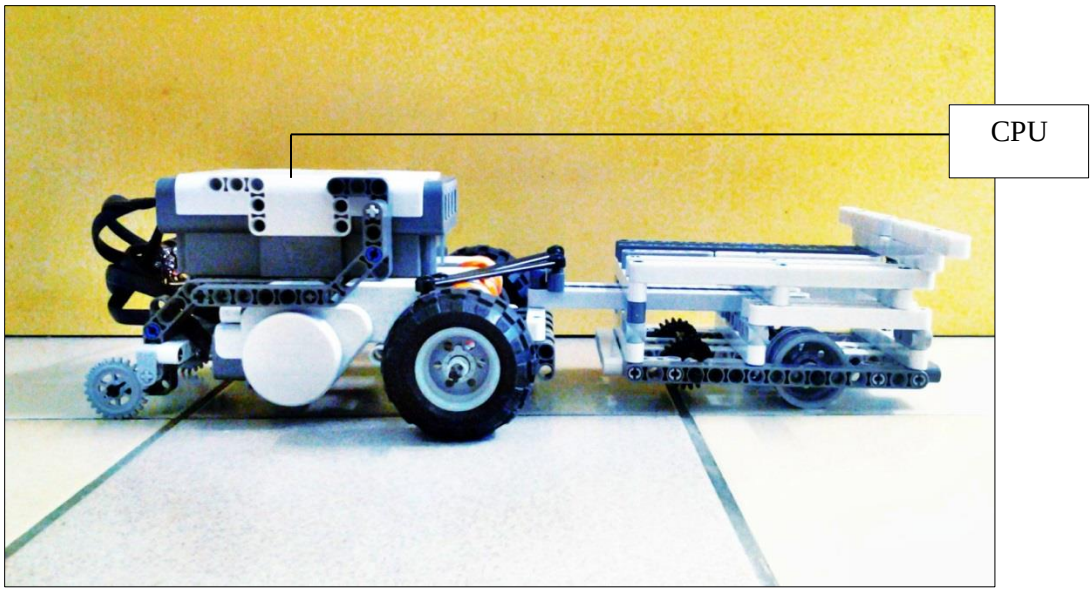


FIGURE 4.1: Side View of Initial Prototype

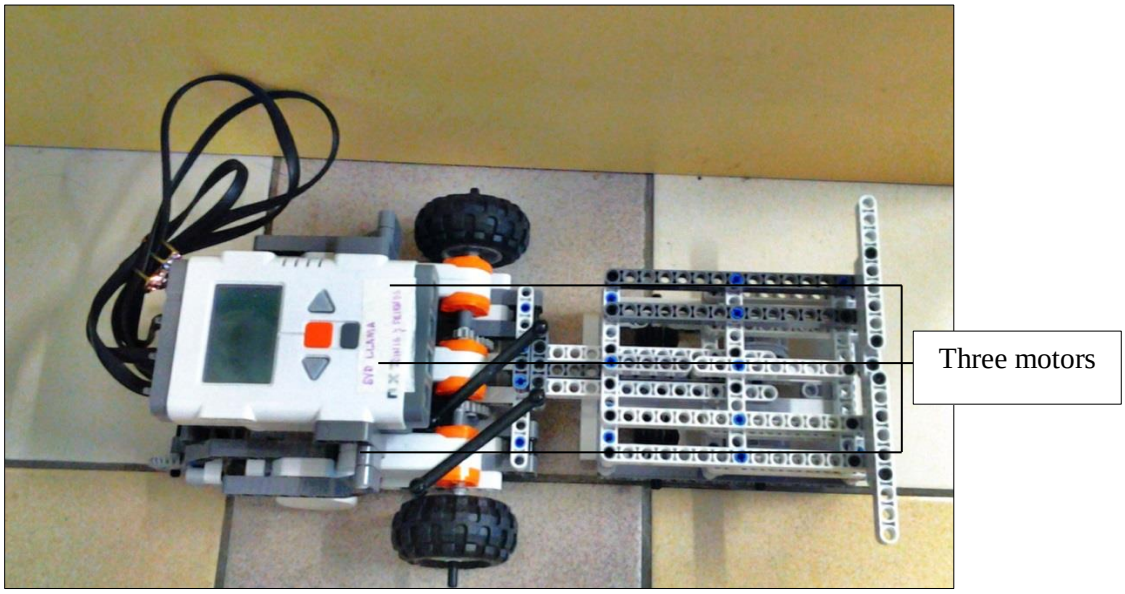


FIGURE 4.2: Top View of Initial Prototype

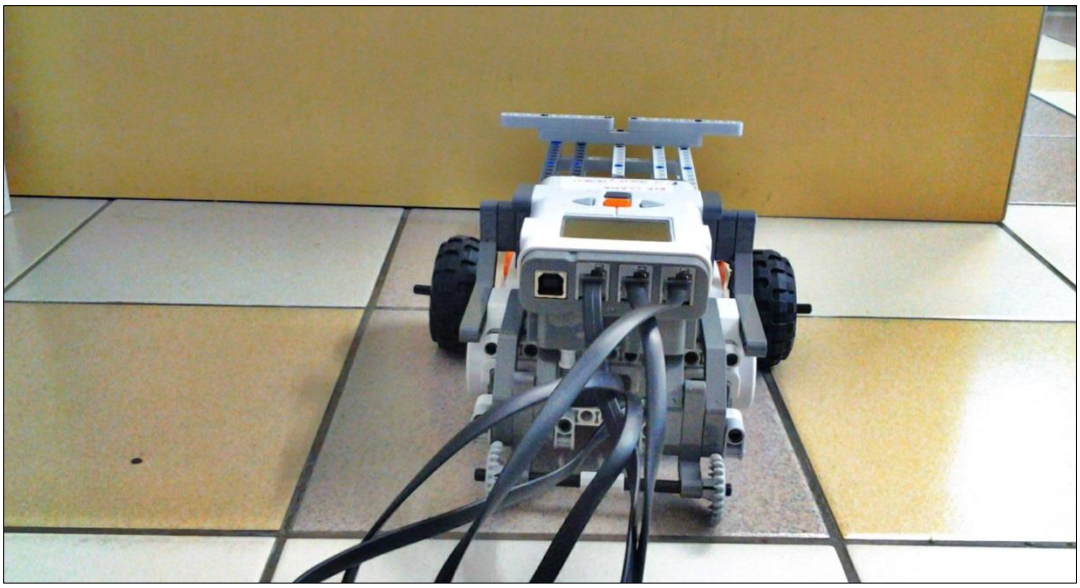


FIGURE 4.3: Front View of Initial Prototype

4.1.2 Final Design of Robot

The initial designed was modified by attaching sensors to it in order to fulfill the functionalities needed.

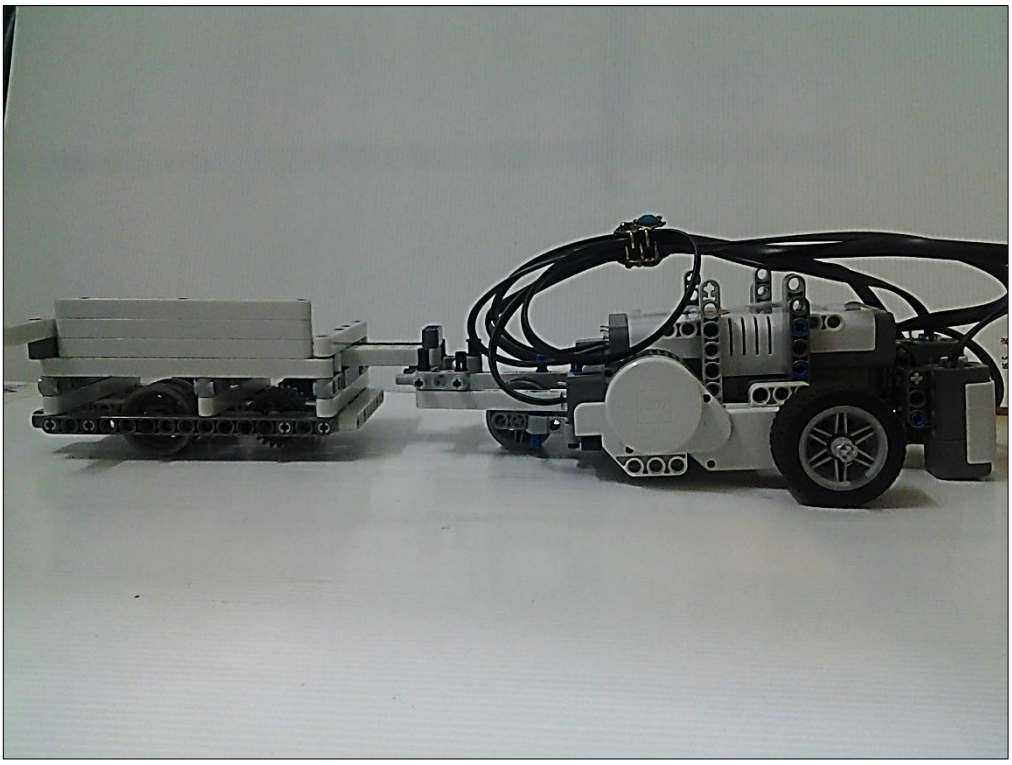


FIGURE 4.4: Side View of Final Prototype

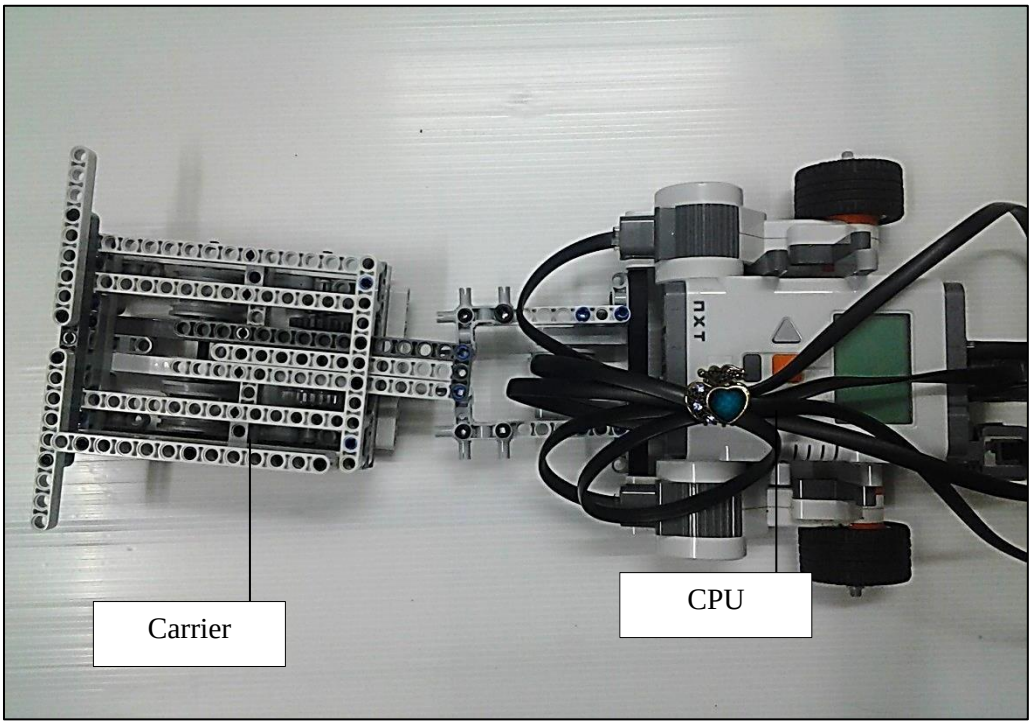


FIGURE 4.5: Top View of Final Prototype

FIGURE 4.6: 3D View of Final Prototype

4.2 Load Carrying Test

The second progress that has been achieved is satisfying Book Carrier's first objective which is to investigate load carrying algorithms. This robot is the prototype of a small scale of Lego Librarian. In order to test the simulation of load carrying ability, a few tests have been done. Currently, the CPU of the robot is only programmed to move forward. Experiments to test if it can carry any books on it have been done. Three books were placed on the prototype. Based on my findings, it successfully carried all the three books and moved forward. The speed was relatively decreased when the number of books increased. Figure 4.7shows the prototype carrying those books.

FIGURE 4.7: Prototype Carrying Books

Experiments were done by using few numbers of books of different weight to test the optimum speed the robot would achieve. A distance of 1 meter was fixed to study the speed that the robot could achieve for different weight of loads that it withstands. The diagram below shows the experiment in detail.

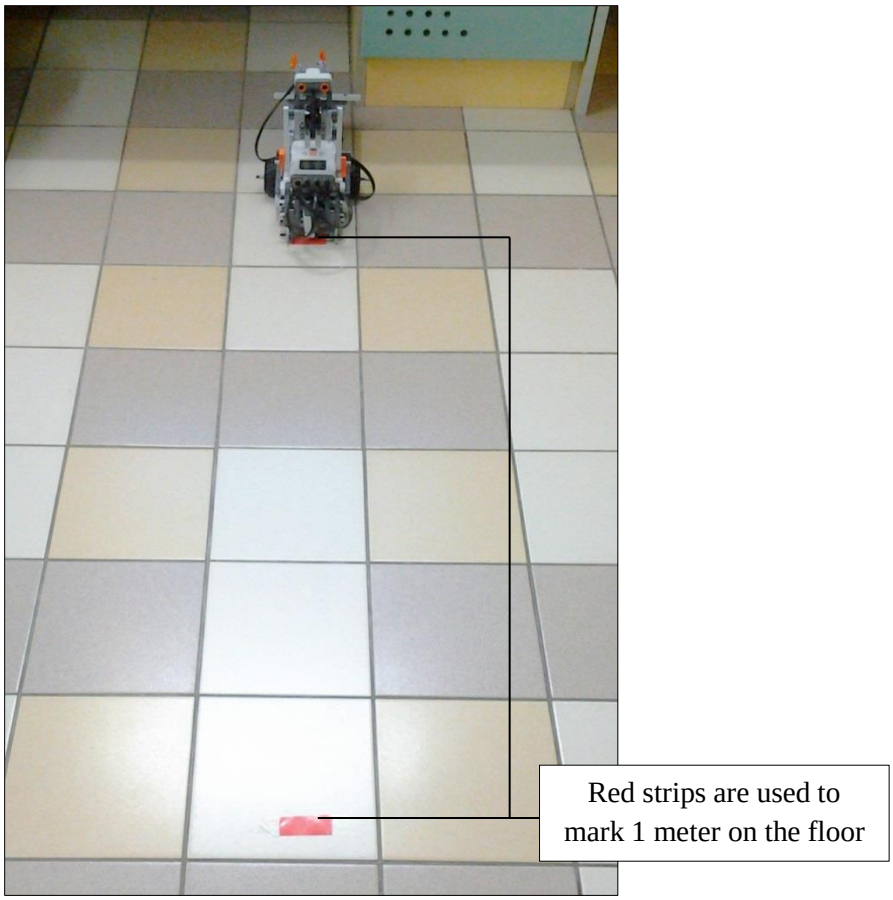


FIGURE 4.8: Experiment Venue

The speed of the robot was becomes slower when the weight increased. The speed of the robot is calculated based on the formula below.

$$\text{Speed } (v) = \frac{\text{Distance } (d)}{\text{Time } (t)}$$

The table 4.1 shows the results of the experiment.

Manipulated Variable: Weight of books (kg)

Fixed Variable: Distance between red strips (1 meter)

Responding Variable: Speed of the robot (ms^{-1})

TABLE 4.1: Weight Test Experiment Result

Distance (m)	Weight of books (kg)	Time taken(s)	Speed (ms^{-1})
1	0.7	19.23	0.052
1	0.8	19.60	0.051
1	0.9	22.22	0.045
1	1.0	26.32	0.038

Based on the table below, it is studied that 1.0kg of load maintained the speed of 0.038 ms^{-1}. When the load increases, it tends to move very slow and eventually stops. Hence, it is more advisable to use books that weigh 1.0 kg for this small scaled system.

4.3 Line Following Test

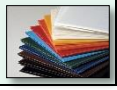
The line following method, is also adapted from my previous Aritificial Intelligence project. Firstly, the project was designed to follow a line, and then it was changed to obstacle avoidance intelligence due so some constraints. The idea line following algorithm that was explained in literature review was also adapted and modified to produce the algorithm in Figure 4.9.When the line following method was programmed, the algorithm was successful. This algorithm will use two light sensors. The algorithm is as follow:

```
if (sensor detect=half black and half line)
        Go straight
If( brightness > 30)
        Make a left turn
Else if(brightness < 30)
        Make a right turn
```

FIGURE 4.9: Line Following Pseudocode

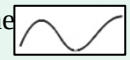
Few tests have been done to test the line following intelligence. Before performing the line following test, the capability of the robot to move on a smooth and a rough surface was tested. Later, the robot was tested on the speed when its moves on a straight line and a curvy line. The results of the experiment are tabulated in table 4.2 and 4.3.

TABLE 4.2: Surface Type Experiment Result

Surface Type	Distance (m)	Time Taken (s)	Speed (ms^{-1})
Rough (Carpet) 	1	15.8	0.062
Smooth (Corrugated Board) 	1	12.7	0.787

The robot is tested on a carpet for the rough surface testing and on a corrugated board for the smooth surface testing. It can be seen that the speed of the robot is higher when moves on a smooth surface compared to rough surface.

TABLE 4.3: Line Type Experiment Result

Line Type	Distance (m)	Time Taken(s)	Speed (ms^{-1})
Straight Line 	1	13.84	0.072
Curvy Line 	1	16.73	0.059

Based on Table 4.3, the robot moves faster on a straight line compared to a curvy line. It moves slower on a curvy line because it takes time to change the motors' power and do the turning s accordingly.

4.4 Stimulating the Intelligence

The line following is implemented using a light sensor and a color sensor is used to detect the color strips on the line. As for testing purpose, the robot will be moving in a straight line. After the programming is done, the robot was tested and it has successfully moved according to the line and stopped when it detects colors other than black. The figure below is the screen capture of the algorithm.

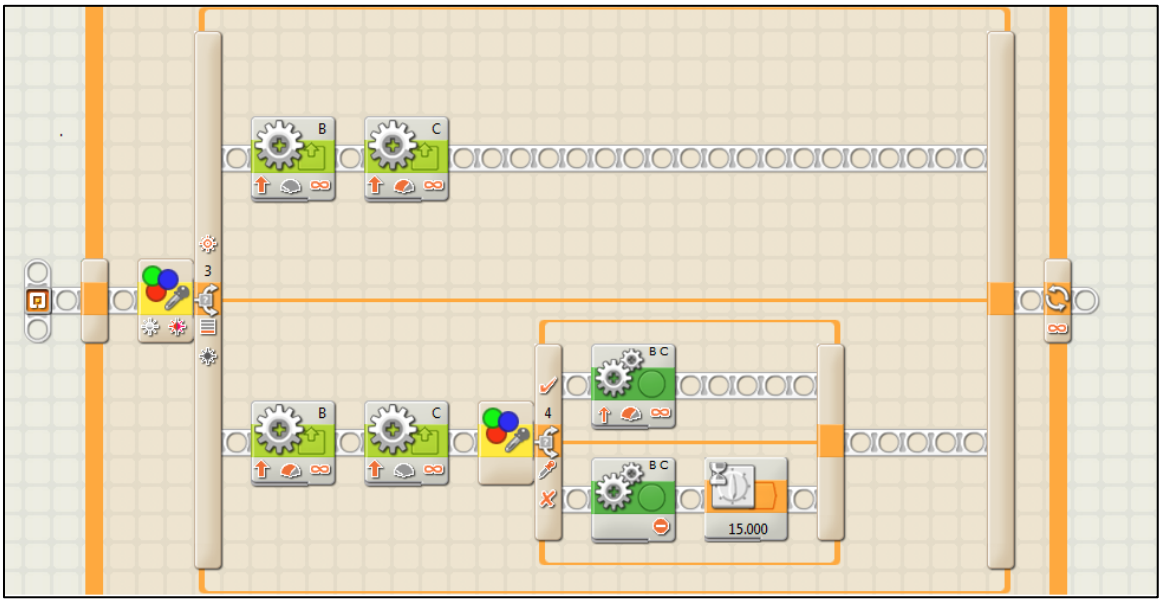


FIGURE 4.10: LEGO Mindstorm IDE Algorithm

The Lego Mindstorms NXT 2.0 kit provides an IDE for users to perform visual programming of the machines, using readily made and available modules that grant users full access to all of the features in the kit. Hence, in FYP II, the algorithm is programmed and tested. Addition to the betterment of the intelligence will also be done.

4.5 Surveys and Feedbacks

4.5.1 Corporate Social Responsibility (CSR) Project with SMK Jelai, Perak

An YSR was done under the Computer and Science department in UTP with SMK Jelai students on 19th April 2014, Wednesday, 3pm to 4pm. The survey was conducted with school kids as they have the experience in using the school library. They understand the concept of Lego Librarian easily. It is an opportunity used to reach the public about the idea of Lego Librarian. We joined the project and did a demonstration of our project. Since Lego Librarian is closely related to their school library, a survey was given to them to obtain their feedback. A questionnaire was given to all the students to rate our project. The details of the participants are recorded in table 4.4.

TABLE 4.4: Participants' Details

No of participants	80
Age group	16 – 17 years

Figures 4.11 and 4.12 show some pictures that were taken during the demonstration.

FIGURE 4.11: Demonstration Session

FIGURE 4.12: Demonstration Session

There were few questions asked in the questionnaire. The questions were grouped into four categories which are awareness of AI, attractiveness of project's design, usefulness of the project idea and alternative industries that the concept can be applied to.

Figure 4.13 refers to the first category, awareness of AI. Before proceeding for our project, we thought that it is necessary for the students to understand the existence of AI. This question is designed in a way to investigate the percentage of students that are aware of AI.

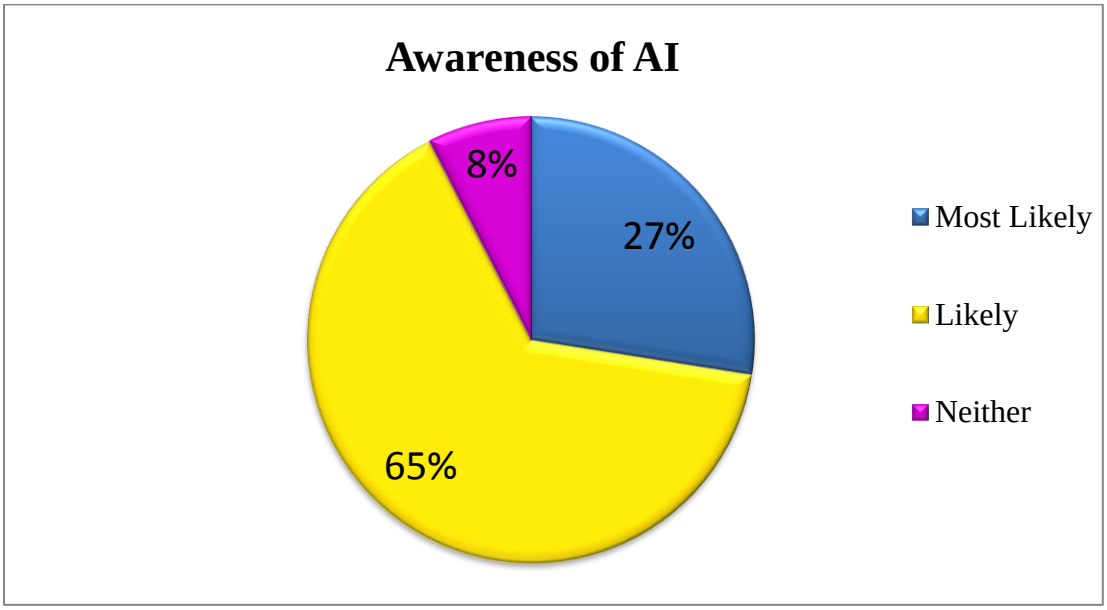


FIGURE 4.13: Awareness of AI Survey Result

It is clear that 73% of the students are aware of the existence and the balance does not really give any bold answers. It is believed that Lego Librarian increased the awareness of AI in each of them.

Figure 4.14 has focused more on the project. It is to study the attractiveness of the designs of the robots in a student's perspective.

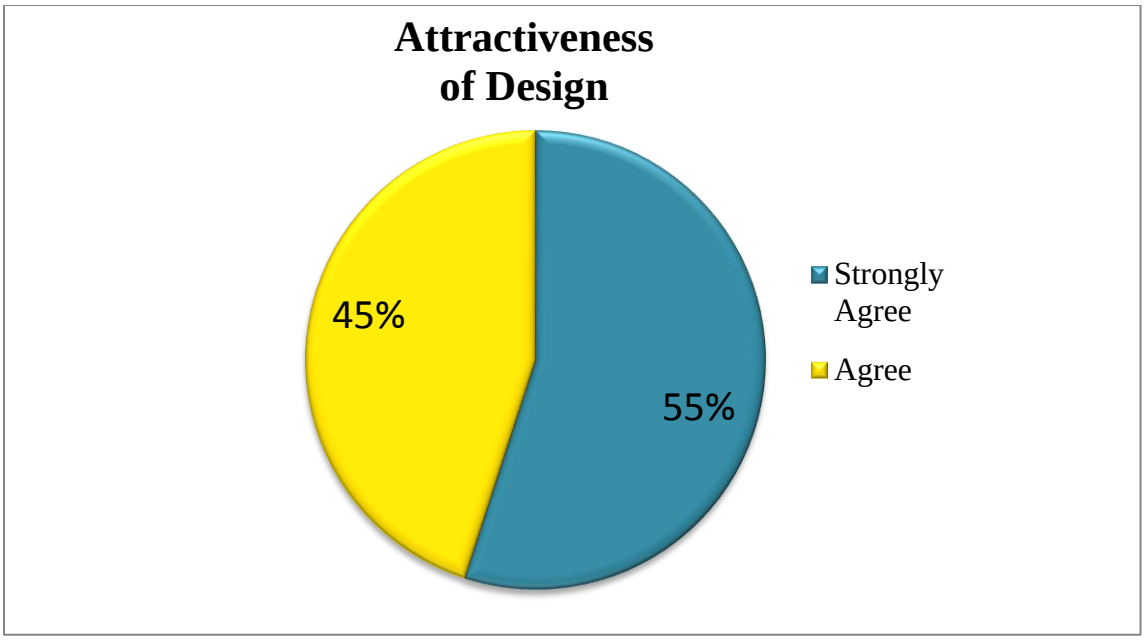


FIGURE 4.14: Attractiveness of Design Survey Result

100% agreed that the design was attractive. They clearly understood that the robot was built using the LEGO Mindstorms NXT 2.0 kit and was very interested when they were given a chance to try building something new based on their own creativity.

Figure 4.15 shows the results of students' opinion on the usefulness of the project's idea if it is being developed in a bigger scale in the aspect of library management system.

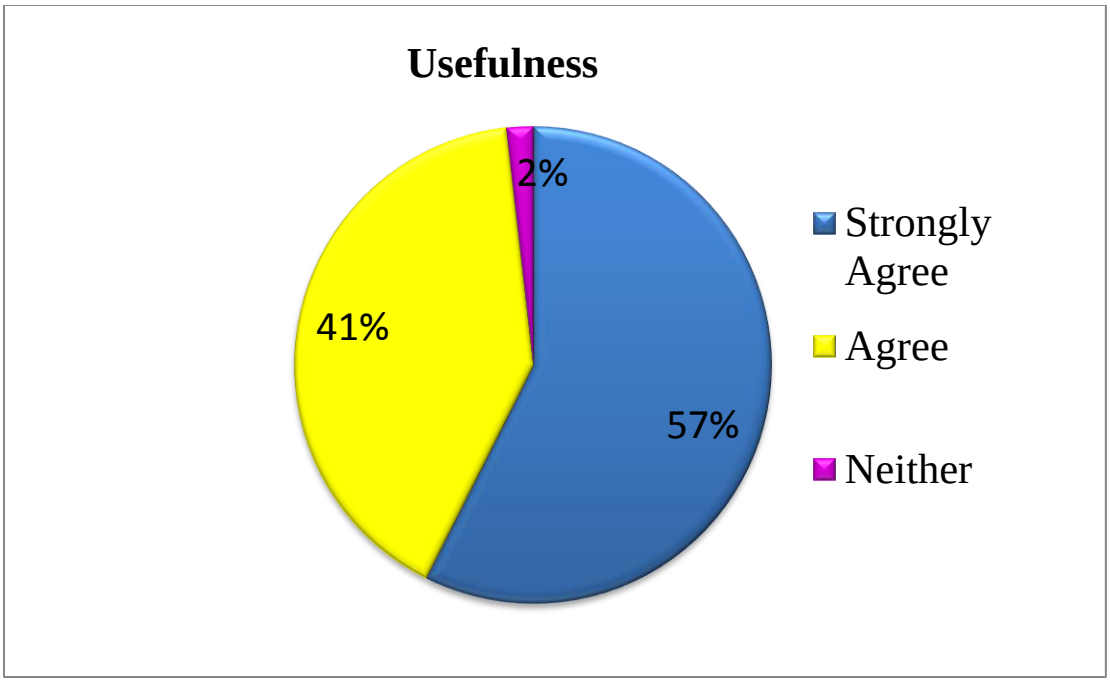


FIGURE 4.15: Usefulness of Project Survey Result

Based on the pie chart above, 98% of the students believed that the idea will be useful in future development. They agreed that it will reduce the human energy as well as saves time if these robots are implemented in libraries.

Figure 4.16 shows the alternative industries in which the concept of Lego Librarian can be applied. Few options were given for the students to choose and the result is as shown below.

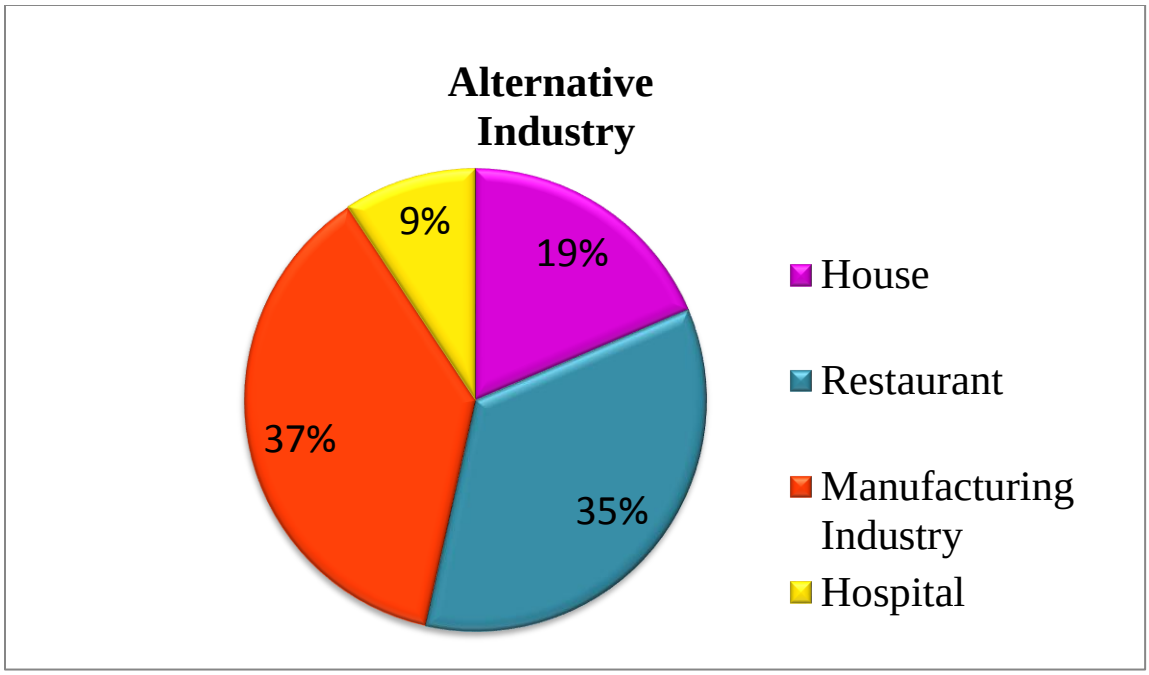


FIGURE 4.16: Alternative Industry Survey Result

Manufacturing industry is the highest percentage of students' selection. Secondly, restaurant and followed by house and hospitals. In manufacturing industries, especially at the storage department, this robot will be useful to carry heavy loads as well as lifting it to its shelves.

4.5.1 Acceptance Test with IRC, UTP Staff

A short acceptance test was implemented in IRC UTP with the staff working there on 1st April 2014, Monday, 11am to 1pm.

TABLE 4.5: Participants' Details

No of participants	5
Age group	25-40

A short demonstration was done and the functionalities were explained to the participants. They were allowed to ask few questions regarding our project after the demonstration. Later, we

interviewed them on their opinion on the project. The feedback session was informal but a video was taken to record their feedback. Figure 4.17 shows one of the participant giving their feedback on the robots.

FIGURE 4.17: Participants Conveying Feedback

Some of the participants' feedback on our project that was captured in the video is tabulated in Table 4.6:

TABLE 4.5: Feedback Results

Positive Feedback	**Negative Feedback**
Good Design	Cables should be arranged neatly
Clear functionality	Costs will be high if developed in a bigger scale
Outstanding Idea	Robots usage in industries reduces job opportunities for humans
Helpful if developed in a larger scale	
Rating of project : 9.5	

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This project, a small scale mobile load carrier is used to prove the importance of robot in humans' daily life. Since this project is focusing on solving the problem in IRC UTP, it is hoped that Lego Librarian will help to solve the problem one day if it is developed in a bigger scale. This smaller version of Lego Librarian will help people to understand the real concept if it is applied in a real world.

5.2 Achieved Objectives

Three objectives have been achieved in this project. Investigation on load carrying and line following algorithm are done and the best algorithm is selected to be used. Besides, a lab-scaled robot that is able to carry books from collection counter to the shelves with following line ability has also been developed. Testing is thoroughly done with the target users on a lab-scaled mode.

5.3 Project Reusability

Feedbacks proved that Lego Librarian that is developed in a bigger scale can also be applied in alternative industries such as manufacturing industries and restaurants. Based on the experiments conducted, the robot can withstand a maximum weight of 1kg for a minimum of 1 m distance on both straight and curvy lines. For future work, materials that can be used for the robot if it is developed in a bigger scale should be studied.

REFERENCES

Appiah-Berko, K., Dykhuis, A., Helmus, T., & Maduagwu, N. (2012). “The Librarian” A Library Book Indexing Robot. In Calvin College.

Dean, T., & Fleming, P. (2002). Trunking efficiency in multi-carrier CDMA systems. In *Vehicular Technology Conference, 2002. Proceedings. VTC 2002-Fall. 2002 IEEE 56th* (Vol. 1, 156-160). IEEE.pp.

Dupuis, J. F., & Parizeau, M. (2006, June). Evolving a vision-based line-following robot controller. In Computer and Robot Vision, 2006. The 3rd Canadian Conference on (pp. 75-75). IEEE.

E Rich, K. K. (2007). Artificial Intelligence. McGraw-Hill.

Faizan, M., & Ahmad, B. (2008). Obstacle avoidance legged robot (Doctoral dissertation, Universiti Malaysia Pahang).

Ghani, A., & A'Alam, K. (2007). Obstacle avoidance mobile robot (Doctoral dissertation, Universiti Malaysia Pahang).

Ikeura, R., Moriguchi, T., & Mizutani, K. (2002). Optimal variable impedance control for a robot and its application to lifting an object with a human. In *Robot and Human Interactive Communication, 2002. Proceedings. 11th IEEE International Workshop on* (pp. 500-505). IEEE.

Kosuge, K., Sato, M., & Kazamura, N. (2000). Mobile robot helper. In *Robotics and Automation, 2000. Proceedings. ICRA'00. IEEE International Conference on* (Vol. 1, pp. 583-588). IEEE.

Li, T. H., Chang, S. J., & Tong, W. (2004). Fuzzy target tracking control of autonomous mobile robots by using infrared sensors. *Fuzzy Systems, IEEE Transactions on*, *12*(4), 491-501.

Mobile Robot. (n.d.). Retrieved from http://en.wikipedia.org/wiki/Mobile_robot

Mobile Robot. (n.d.). Retrieved from http://www.shifz.com/2006/05/scoobie-doo-tactical-mobile-robot.html

Prats, M., Sanz, P.J., & Pobil, AP. D. (2005). *Model-based Tracking and Hybrid Force/Vision Control for the UJI Librarian Robot.* Retrieved from Robotic Intelligence Laboratory, Jaume-I University Castellon, Spain.

Shibata, T., Fukuda, T., & Tanie, K. (1993, October). Fuzzy critic for robotic motion planning by genetic algorithm in hierarchical intelligent control. In *Neural Networks*,

1993. IJCNN'93-Nagoya. Proceedings of 1993 International Joint Conference on (Vol. 1, pp. 770-773). IEEE.

Thirumurugan, J., Kartheeswaran, G., Vinoth, M., & Vishwanathan, M. (2010, December). Line following robot for library inventory management system. InEmerging Trends in Robotics and Communication Technologies (INTERACT), 2010 International Conference on (pp. 1-3). IEEE.

Wang, W. J., & Chang, J. W. (2012, June). Implementation of a mobile robot for people following. In *System Science and Engineering (ICSSE), 2012 International Conference on* (pp. 112-116). IEEE.

Yoshimi, T., Nishiyama, M., Sonoura, T., Nakamoto, H., Tokura, S., Sato, H., ... & Mizoguchi, H. (2006, October). Development of a person following robot with vision based target detection. In *Intelligent Robots and Systems, 2006 IEEE/RSJ International Conference on* (pp. 5286-5291). IEEE.

APPENDICES

Appendix (i) Questionnaire

The following questionnaire sample contains 10 questions. This questionnaire is to obtain feedback for our Final Year Project. Please fill in your information and tick (√) the preferred options.

Name: _____ Age: _____ Gender: M/F

Occupation: _____

Please indicate whether you agree or disagree with the following statements.

1. Are you aware of Artificial Intelligence (AI) field of study in Information and Communication Technology?

☐ Strongly Agree ☐ Agree ☐ Neither Agree or Disagree ☐ Disagree ☐ Strongly Disagree

2. I believe AI is a good field to pursue my studies for my tertiary education.

☐ Strongly Agree ☐ Agree ☐ Neither Agree or Disagree ☐ Disagree ☐ Strongly Disagree

3. The design of Lego Librarian is attractive.

☐ Strongly Agree ☐ Agree ☐ Neither Agree or Disagree ☐ Disagree ☐ Strongly Disagree

4. Lego Librarian is useful and helpful for human in the aspect of library management system.

☐ Strongly Agree ☐ Agree ☐ Neither Agree or Disagree ☐ Disagree ☐ Strongly Disagree

5. Lego Librarian will be able to achieve good market position if it is commercialized.

☐ Strongly Agree ☐ Agree ☐ Neither Agree or Disagree ☐ Disagree ☐ Strongly Disagree

Please tick on the preferred box.

1. How robots should look like and interact?

   ☐ Big machine ☐ Small machine ☐ Human Animal ☐ Others: _____

2. In which area do you think that Lego Librarian can replace humans other than libraries?

   ☐ House ☐ Manufacturing Companies ☐ Hospital

   ☐ Restaurant ☐ Others (please state): _____