UNIVERSITI TEKNOLOGI PETRONAS (UTP)

LEGO Librarian: Book Sorter

By

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Dissertation submitted in partial fulfilment of

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the

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Approved by,

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UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

January 2014

January 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 reference and acknowledgements, and that the original work contained herein has not been undertaken or done by unspecified sources or persons.

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(SITI DZULAIQHA BINTI ISMAIL)

ABSTRACT

Manual book sorting is time consuming and laborious. Traditionally, human librarians have to get the books from the circulation desk to be sorted and carry the books around to the right locations and putting it on the right shelf. It is prone to misplacement of books in the library. It is quite difficult and seems impractical to return the books back to the original locations daily. To overcome this problem, a book sorting robot known as Book Sorter, a small scaled prototype has been proposed as a simulation of an efficient method to ease the daunting task of librarians in the manual organisation of books. It is also proposed to provide a better allocation of resources of a library. Book Sorter is built as a robot that compliments another robot in LEGO Librarian called Book Carrier. LEGO Librarian is an automated system that is used for organising books on the shelf at the library. The scope of study for this project involves the current system used in the UTP library as well as the robotics application in the librarian system that covers some chapters of study. The activity diagram describes the overall process flow of the system and the development methodology used in this project is throwaway prototyping.. Several interview, survey, field test and acceptance testing were conducted and briefly discussed in Chapter 4. This project is expected to have vast potential to provide a view in real life especially in its capability to alleviate the intensive labours and efforts (time) in sorting the books automatically onto the right shelves.

ACKNOLEDGEMENT

First and foremost, I would like to take this opportunity to express my greatest gratitude and appreciation to my supervisor, Pn Norshuhani binti Zamin, who has giving me full assistance throughout the course. She has been providing her guidance in all aspects of research and development for my project, Lego Librarian: Book Sorter. Besides, I am so much grateful for been giving a lot of chances to join many of her events such as IT talks, exhibitions, educational trip and etc.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

PROJECT BACKGROUND

1.1 Introduction

The world is occupied by the living and non-living things which is the latter are nowadays can possibly imitate what the living things capable of. Apparently, what can clearly be seen through the globe is changing. Everything is deserved for a change over the lifetime and this is what people are doing by programming their ability into non-living things called automated robot. According to Marsh (2004), the robotics industry was first started in 1961 when George Devol and Joe Engelberger placed the first robot in the General Motors, putting it on the factory floor. It has been about 52 years that the robotics industry is living well in this world. Their legacy keeps growing and has already found their way into many fields such as healthcare (surgery), scientific laboratories, gaming activities, rescue services and etc.

The well-known Australian roboticist was popularizing the actionist approach for robotics quoted “robotic revolution” is imminent (Milojevic & Sabanovic, 2013). It was continued to be more convincing when Bill Gates who was an American business magnate had a worldwide expectation saying “robots in every home” while the Japanese Government agreed and supported the “partner robots” development. It is believed that robotic is a key growth of industry. In the key recognition of the technological advances, library is a strategic location to evolve to be more automated. The robotics application can be implemented in such real life scenario where the most needed thing is manipulation.

1.2 Project Background

This project is aimed to provide an automated solution for sorting books on the shelves at the libraries. According to White (2002), sorting is started from discharging the books from the circulation desk to putting on the trolley for the sorting staff to come and sort the book on the trolley. He will then arrange the books on the trolley by following the right order. After that, he will bring the trolley of sorted books to the right shelf and place the book onto the first shelf to be indicated by the shelving group to slot in the books. This project is basically based on the problems found in the current manual library management system, specifically for sorting task.

1.3 Problem Statement

Practically, manual book sorting is time consuming and laborious. This laborious task can create a critical problem such as misplacing books in the library. Commonly, the misplaced books are caused by the librarian who is in charge of placing the returned book. Additionally, a case study reported at Hekman Library of Calvin College has motivated this research to leverage the knowledge. Appiah-Berko et al. (2012) identified that the library owns over 17 million texts. It has caught a global eyes when 'The Chimes' has issued a case on 16 September 2011, that states "any book placed incorrectly is most likely lost until the next shelf reading session" that is possible to be dragged out and takes about 1 year time.

The significance of this project is to introduce 'Book Sorter', as a mini robot that is capable to make a decision based on colours to demonstrate its capability in determining which books for which shelf. It is programmed to detect 2 different colours and performs actions based on the colour detected. Then, Book Sorter is able to autonomously traverse the aisles by carrying the scanned (color of the sticker) books and expected to lift up the book on to the right shelf. 'Book Sorter' is defined as a robot that compliments another robot namely, 'Book Carrier' in LEGO Librarian project. LEGO Librarian is a mobile automated system that is used for books sorting

in the library, which works from the circulation desk until placing the books on the shelf.

1.4 Objectives

The general objective of LEGO Librarian is:

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

The specific objectives of Book Sorter are:

1. To investigate book scanning, lifting and sorting process
2. To develop a robot capable of scanning and picking the book from the book carrier onto the shelves

1.5 Scope of Study

The scope of this project will involve a study within the following areas:

1. The current system used at the Universiti Teknologi PETRONAS (UTP) library with regard to books' organisation
2. Robotic application in a librarian system that covers the study on:
    i. Mobile automated system
    ii. Book scanning
    iii. Book sorting
    iv. Book lifting

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Globally, there are a lot of conferences on robotics such as IROS, ICRA, etc. being held (Ramos-Garijo et al., 2003). It indicates that the robotic application has widely been used around the world which has also implies that the number of research in this particular area is increasing. Many researches have been dedicated in studying the field of robotics extensively as well as delegates from various industries have started to join robotics conference in leveraging their knowledge and ideas of developing intelligent robots.

2.2 Artificial Intelligence

Artificial Intelligence (AI) is defined as the science of developing machines that can act intelligently and the study of ideas will make the intelligence into reality (Murphy, 2000). According to Nilsson (1998), the intelligent behaviour is translated through communication, reasoning and perception, learning and acting in multifaceted environment. A machine that is capable of performing all these activities as similar to what human can do or beyond the human' capability are considered intelligent and adaptive.

The book written by Murphy (2010) has also conceded that AI context is broad and one part of AI is the study of AI robotics. It is the study on how the techniques of AI application are transferred to a robot. The robots is defined as an intelligent machine that has been programmed as people perceived it as the clone of human being (human-like). The intelligent robots can be used for any application regardless the nature of the environments. For instances, it is widely being used in the industries such as military, agriculture, healthcare, services, space, nuclear, rescue and others.

2.3 Robotics Application in Industries

A Newsweek issue has written an article entitled, 'Actually, Chess is Easy', (Murphy, 2010). It is briefly discussed on the reasons behind the highly demand of robot applications than playing chess. It is closely related to the robotics paradigm that is considered as predictions or techniques (philosophy). This explained on the approach of problems' class. It involves examining the environment and solving the problems using a set of tools. This article as well stated that it does not necessary for a paradigm to be right because there are possibility of others paradigm emerging to suit the case. Thus, different approaches are applied to the different problems. To be exact, the problems will be easily solved by applying the right paradigm to it. Relatively, the key success of programming a robot for a particular application is to identify the right paradigms of AI robotics.

Kaneko et al. (2002) is work presented that historically, the robots are typically invented for industrial automation and environmental plays which has no relation to human lives. However in this era of globalization, the demand has changed. Robotics application that is related to human lives and activities is more preferable and in needs than the traditional robots for industrial automation. The society is expected for the robots that can assist their daily lives such as healthcare, offices, warehouse, libraries and home.

2.3.1 Robotics Application for Library

A robotics librarian is proposed to receive command from the user on the details of the book required and is programmed to interpret it as a result of bringing the requested book to that particular user (Ramos-Garijo et al., 2003). The overall system descriptions of the robot are described in Figure 2.1 and Table 2.1;

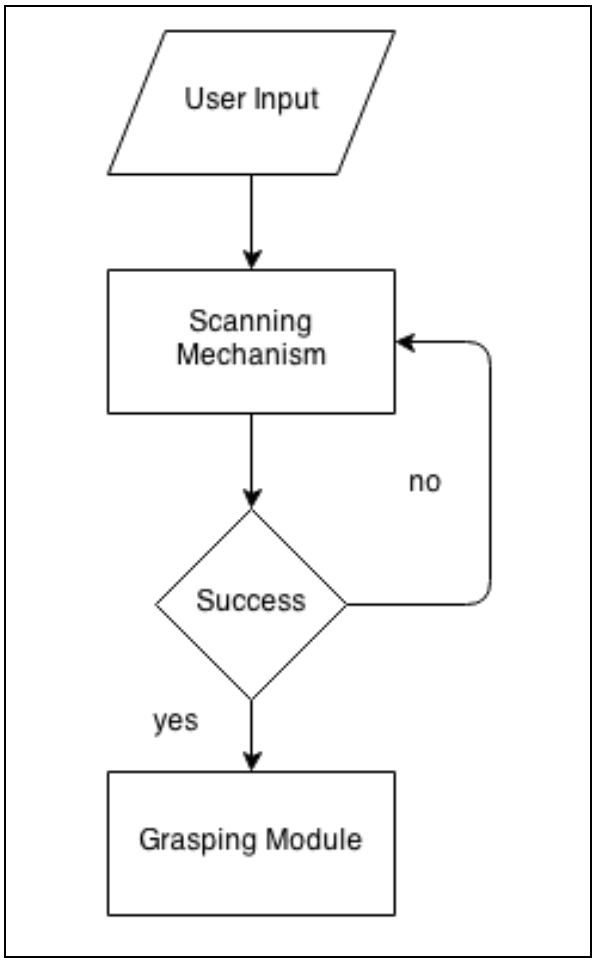


FIGURE 2.1: System's Functionality

Source: Ramos-Garijo, R., Prats, M., Sanz, P. J., & Del Pobil, A. P. (2003, October). An autonomous assistant robot for book manipulation in a library. In *Systems, Man and Cybernetics, 2003. IEEE International Conference on* (Vol. 4, pp. 3912-3917). IEEE.

TABLE 2.1: System's Description

Module	**Descriptions**
User Input	The robot is made to interact with the users by permitting them to use voice command. The command will be translated by using database and pass to the next module.
Scanning Mechanism	Receiving the translated command. The robot is started to seek for the requested book. Optical Character Recognition module is included here. The images (label) captured using the camera will be translated to an authentic text labels (characters) that will be tally with the database.
Success	If the label is found, it moves to the next module and the system will keep scanning is the searching is unmatched.
Grasping Module	It used the combination of visual sensory information and processing force to grasp the needed book.

Source: Ramos-Garijo, R., Prats, M., Sanz, P. J., & Del Pobil, A. P. (2003, October). An autonomous assistant robot for book manipulation in a library. In *Systems, Man and Cybernetics, 2003. IEEE International Conference on* (Vol. 4, pp. 3912-3917). IEEE.

Besides that, two existing applications are summarized in Table 2.2 for a comparison to be made for Lego Librarian: Book Sorter in term of their properties.

TABLE 2.2: Existing Application

Application / Properties	Mobile Robot (Li et. al.,2012)	Librarian Robot (Sarma, et. al.,2007)
Functionality	Search books in the library	Search misplaced books
Scanning Mechanism	RFID reader	RFID tag reader
Cost	High	High
Complexity	High	High
Advantage	Large information storage	Long identification system

2.4 Mobile Automated Robot

In the earthy work, the mobile robots have to be linked via wireless device or cable and controlled by the massive and expensive computer system. As they develop nowadays mobile robots can be built in a small size that can be carried everywhere (Braunl, 2008). According to Warwick et al. (2012), it is either embedded or linked via umbilical connection or wireless that comes along with various sensors and actuators that are controlled by small and inexpensive computer systems. Mobile automated robot can be developed to operate or compute unlimited functionality based on the programming code.

2.4.1 Object Lifting

According to Ikeda et al. (2008), a mobile robot that consists of forklift is only capable of lifting up an object that has the lesser or same weight with itself. In order to ensure its stability during the lifting process, it is very crucial to measure the weight of the object that needs to be lifted up. Besides that, another factor that has to be considered in developing forklift robot is on how to move while carrying the object on the forklift, (Jubeh & Zundorf, 2008). This is done by having a caster at the bottom part of the fork. The caster is used to reduce the friction between the fork and the floor.

2.4.2 Object Scanning and Sorting Mechanism

Sorting mechanism is widely used in robotic industry such as warehouses, supermarkets and libraries. Bdiwi and Suchy (2012) emphasized that the most effective way in sorting is by using vision control system. It can save the time of fault detection and costs. It used Sony XCD-700 camera mounted at the body of the robot that was meant for detecting the alphabetic code system. The algorithm of sorting includes scanning for the objects e.g. book, detect their characteristics, recognize the unique code for each of them and the deciding which object to pick. It is also supported by Prats (2005) where he stated that the vision module is highly capable in scanning the objects. In a library context, the vision module is placed on

the robot to identify the book tags and the tags have to be segmented and located in the image. In addition, the labels must be placed consistently in height, they cannot overlap, they have to be in the same size in rectangular shape and they have to be in a static environment.

2.4.3 Obstacle Avoidance

According to Chen and Huang (2012), it is highly feasible to adopt 4 degrees of freedom for a mechanical structure of using Lego Mindstorms NXT. In order to detect environmental information, sense obstacles and to process few motions such as moving forward, left-turn and right-turn. After that, a decision tree is drawn by referring to the information acquired from the sensors attached to the robot. A decision tree is purposely proposed for the robot to adopt in avoiding obstacles to reach the finishing line. It is indicated as solution that consists of walking motion of the robot. The four sensors are labelled with number 1, 2, 3 and 4. The sensors that are free from obstacle will determine the moving motion of the robot. For instance, the sensor 4 which is located at the right side of the robot is not giving any signal that shows the existence of any obstacle, it brings the means that the robot has to do the right turning.

2.5 Tools

2.5.1 The Robot Hardware (Sensors)

According to a research paper entitled ‘Simple Robotics with Fujaba’, a robot that is successfully used in teaching software development at university called Fujaba was first introduced in 2008, (Jubeh & Zundorf, 2008). In addition, forklift robot should have used two chains which are used for the robot to have a precise rotation within its footprints. It was emphasised that chains are preferable than wheel because it will ease the software in predicting the turn which is very crucial in determining an exact navigation. Furthermore, a few types of sensors used for Fujaba are discussed below:

The first sensor used for the forklift is ultrasonic sensor. It is placed on the fork to detect any obstacle existed in front of the robot. The mounted sensor is also capable to detect when the fork touches the ground. By having this sensor, it will ensure that the distance from the load carried by the fork to the platform is not a problem. On the other hand, another sensor will be placed underside of the robot, mounted a little above from the ground. It is called as light sensor that is used to detect the contrast of the ground. This sensor can only detect the black or white line that the user predetermined on the surface. The sensor will send the detected value to the system to be processed and produce a command to the robot.

The colour sensor is able to read the intensity of the reflected colour towards it (Ferrari & Ferarri, 2011). The intensity value is read for the sensor to identify the colour of the object. I2C interface is used for the sensor to send the value acquire (0-17) to the NXT. It can also pass the raw which is the user can customize the colour name.

Furthermore, the NXT Lego motor has a step counter; it can control the rotation of the motor. It is also called as rotation sensor. It may turn the motor based on the predefined rotation's degree. Therefore, the forklift does not need any other specific sensor to lift the fork. It used constant value (fixed) to detect the upper bound and able to make synchronization with the ground. Whenever the fork touches down, the counter will reset to zero.

2.5.2 Software Architecture

Based on Figure 2.2, Jubeh and Zundorf (2008) have stated that the concrete application model is placed on top of the architecture. F*_API contains the collection of class called FNavigator, FMotor, FNXT, FSensor etc. Each of the classes; F*_Object is associated to adapter instance. It has two functionalities, either of emulating the behaviour or passing the calls to the part of LeJOS packed; ICommand API. The association used for testing purposes. The NXT brick owns LeJOS firmware which is acting as the receiver of the command sent by the ICommand API. The command will be passed in simple byte-array and the communication takes place through a Bluetooth connection.

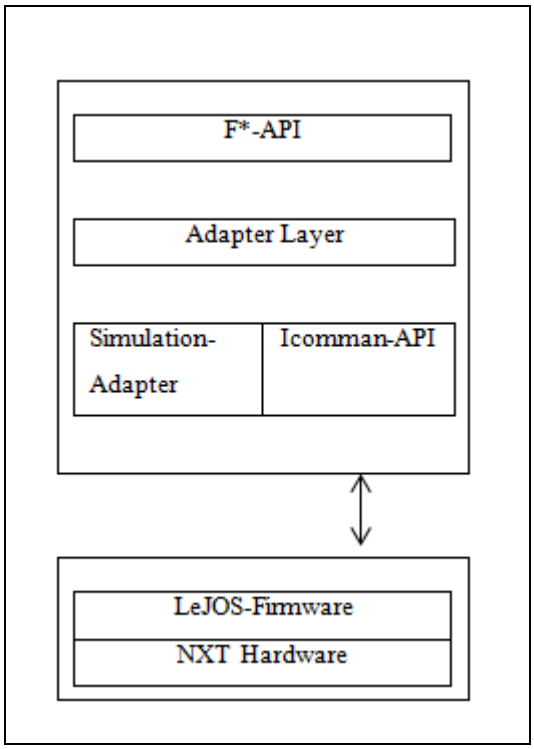


FIGURE 2.2: Software Architecture Layers

Fujaba robot is developed using LeJOS open source java firmware. It includes Java Micro Edition-like API and Java virtual machine. The first one is chosen because it provides ICommand (API) for PCs/Jaba2SE. It is purposely decided to run software on the PC while the NXT is controlled through the Bluetooth connection. The programming language used is Java.

On the other hand, Krag and Korsgaard (2007) has emphasized that there are few other programming language that can be used in simulating the LEGO Mindstorms such as LabVIEW. It is where the user is provided with the graphical interface and has to perform drag and drop way of programming. It is very efficient for the simple programs yet the level of difficulty becomes higher when it comes to a larger system due to numbers of control structures. Another language that is available to use is Not eXactly C (NXC). It is similar to C language but in a way beyond C and can be considered as high level C. It is useful to be used when the programs involves many loops.

2.6 A Case Study of UTP Library

A study has been conducted in the UTP Library. The purpose of having this study is to investigate the current system used in sorting the books at the library. The situation and the book arrangement of the UTP Library is shown in Figure 2.3.

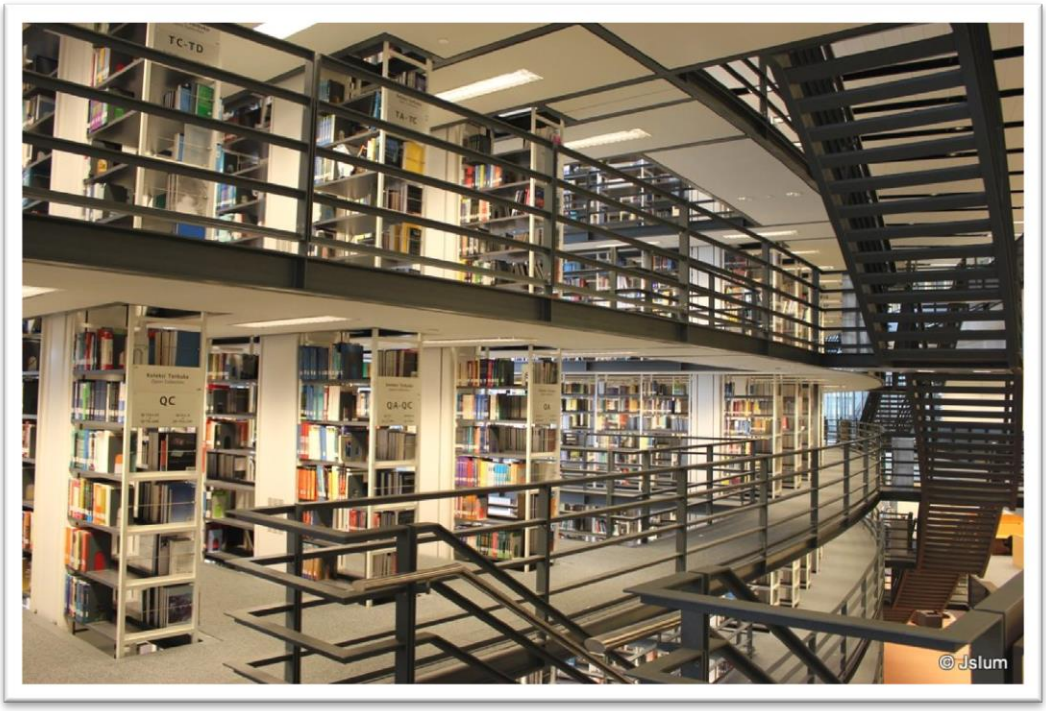


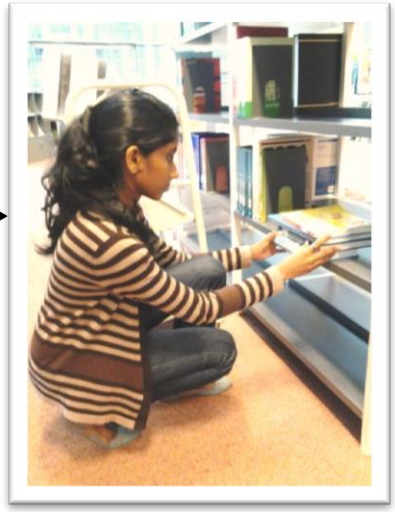
FIGURE 2.3: UTP Library

A librarian (staff) named Mr Faris Syahmi, who is responsible for sorting the books has been interviewed. According to Mr Faris, book sorting required 2 shifts of working as per shown below:

- 8.30am – 10.30am
- 1.00pm – 3.00pm

From his view, book sorting is an activity where it is started from the circulation desk after the circulation staff discharges the books onto the trolley. The librarian who is in charge of book sorting will sort the books on the trolley and

brings that particular trolley to the right shelf of the right level. There are 5 trolleys that are full of books need to be sorted daily that is subject to the season. For example, during the examination week, there will be a lot more of books that have to be sorted. One trolley consists of 100 books and it is specified to one librarian. In total, book sorting requires 5 different labours to complete the task. Specifically, it needs 2 labor in sorting 1 trolley, one is from the circulation desk and another librarian is for sorting the books that requires 1 hour of time. The process flow of books sorting carried out in the UTP library is shown in figure 2.4.



Book returned by the patron (e.g. student) to the circulation desk. Circulation Staff placed the book on the trolley	Sorting librarian sorts the book on the trolley according to shelves and level	The librarian brings the trolley (sorted books) to the respective level	Placed the books on the first level of the shelf; beside the section divider. The section divider consists of the books that has been shelved
↓	↓	↓	↓
Labour A Time Taken: 0	Labour B Time Taken: 30 minutes	Labour B Time Taken: 15 minutes	Labour B Time Taken: 15 minutes

=

Total Labour: 2
Total Time: 1 Hour

FIGURE 2.4: Process Flow

CHAPTER 3

METHODOLOGY

3.1 Introduction

The framework, design, methodology and tools to be used in this project are proposed with regards to the objectives explained in Section 1.4. They are subject to change from time to time for the development and innovation purpose.

3.2 Proposed Framework: Activity Diagram

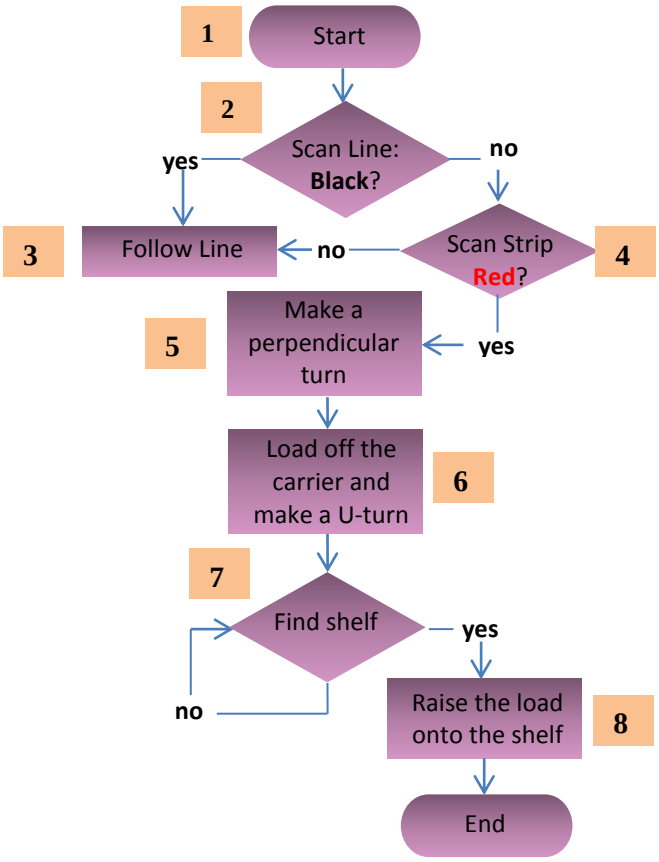


FIGURE 3.1: Activity Diagram

Based on Figure 3.1, by having the objectives to achieve, the process flow of the system as proposed:

(1) *Go to BC.* BS will move to BC location

(2) *Scan* Line. The color sensor sensed the black colour

(3) *Follow line*. If the colour sensor sensed black colour, it will follow the line. The Book Sorter is capable of moving on track by following the black tape on a white corrugated board

(4) Sense the Book. Due to the limitation that LEGO Mindstorms kit has, the best scanning mechanism can be conducted is by using colour sensor. BS sense the colour of the book by scanning the colour strip placed on the floor that belongs to the shelf where the BC is stopped at. The location and representation of the robots are shown in Figure 3.2.

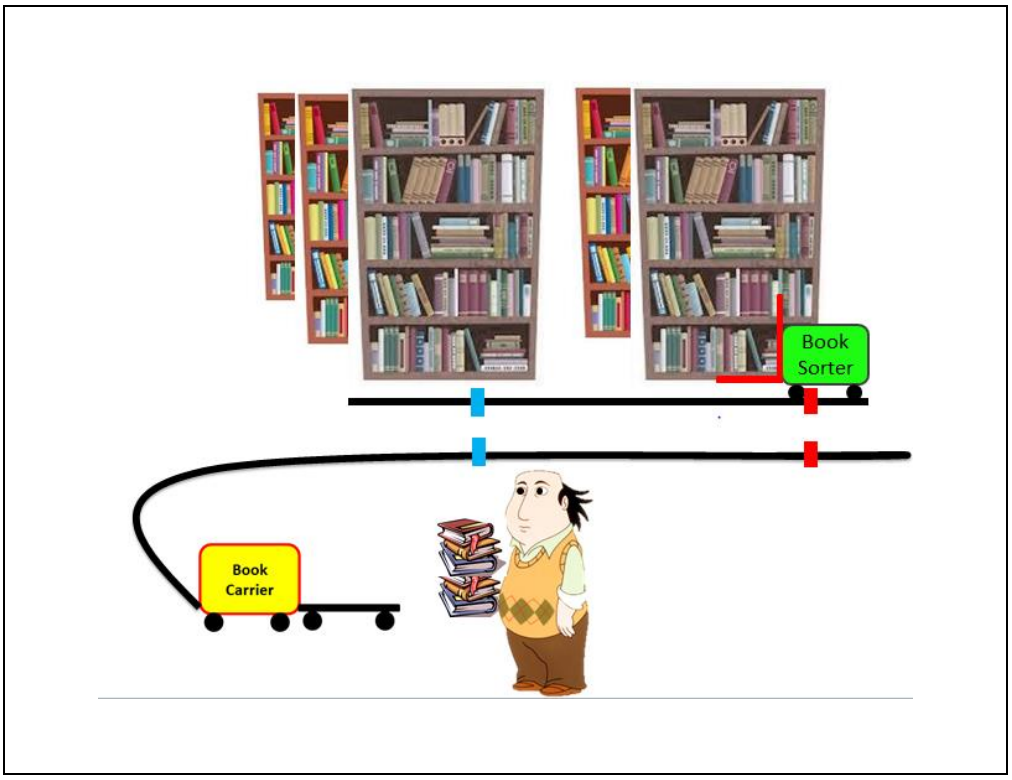


FIGURE 3.2 Simulation of LEGO Librarian

(5) *Make a perpendicular turn.* If the red strip is detected by another colour sensor, the robot will stop and make a perpendicular turn to the left direction

(6) *Load off the carrier*. It will then move in forward direction to the Book Carrier and lift up the book placed on the carrier as per shown in Figure 3.3. 180 degree of turn will be made by the robot in order to be on the right direction in reaching the shelf

(7) *Find shelf.* , the robot will move forward and start to look for the shelf. The ultrasonic sensor is used to detect the shelf

(8) *Raise the load onto the shelf.* If it senses the shelf, it will stop moving and raise the load onto the shelf. Otherwise, it will keep looking for the shelf until it is found.

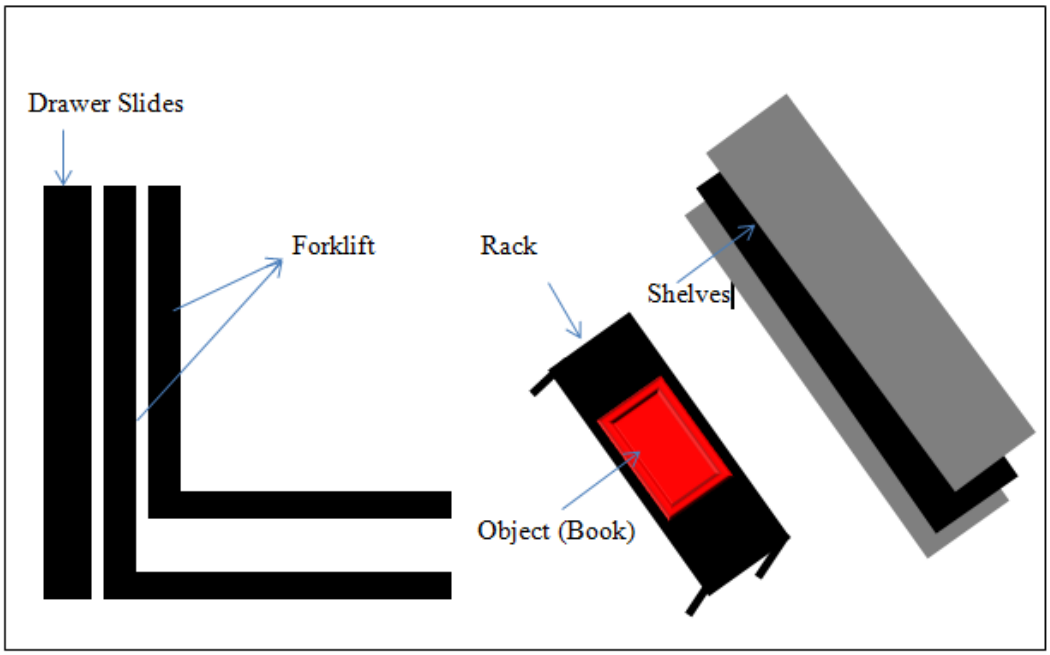


FIGURE 3.3: Design of Book Sorter System

3.3 Book Sorter System Block Diagram

Based on Figure 3.4, Book Sorter is proposed to use three (3) sensors; light, color and ultrasonic. The block diagram of Book Sorter consists of chassis, batteries for the power supply, one microcontroller that acts as the robot's controller based on the NXT program installed inside it and few motors for turning purpose.

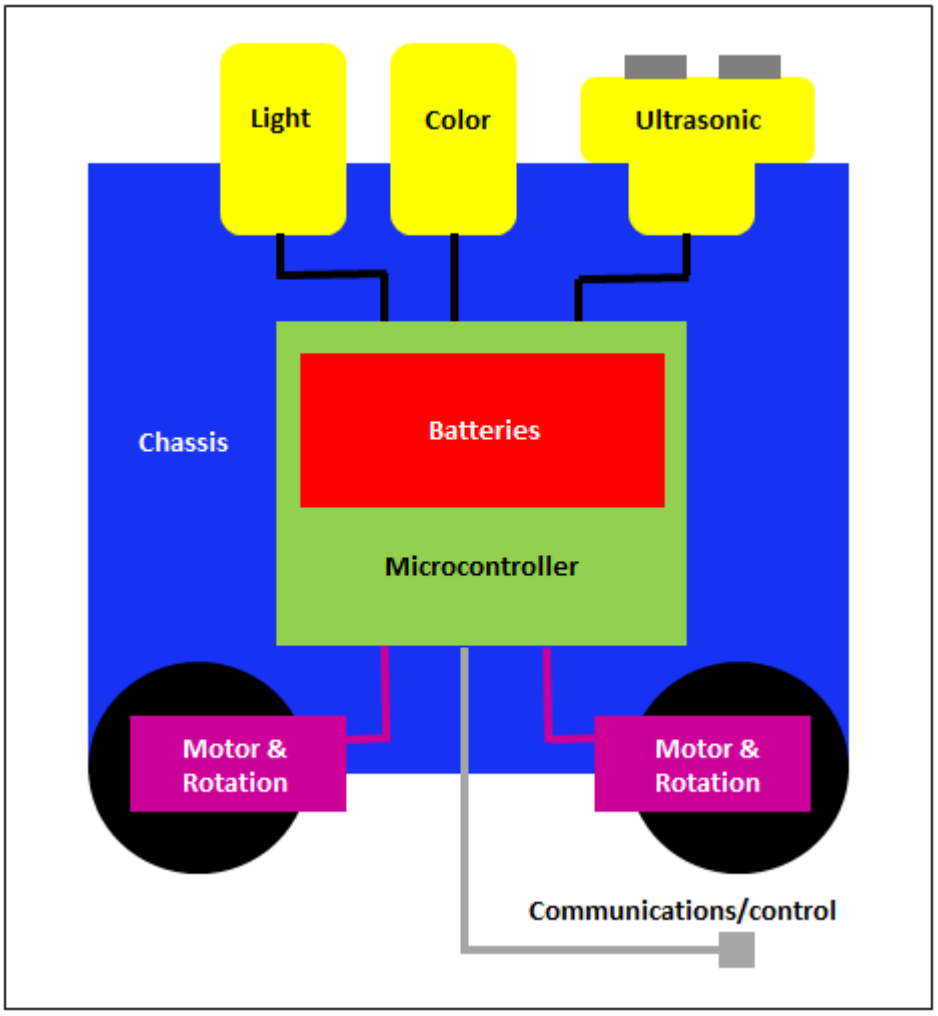


FIGURE 3.4: Book Sorter System Block Diagram

The communication stated in the block diagram is defined as the connection between the software in the PC and microcontroller. The developed program will be inserted into the microcontroller via Bluetooth connection. Referring to Figure 3.5, PC can send the command that is represented in simple byte array as per discussed in the literature review. It will only enable the connection after executing the Java program at PC. The NXT microcontroller will be powered and interpret the command received from PC.

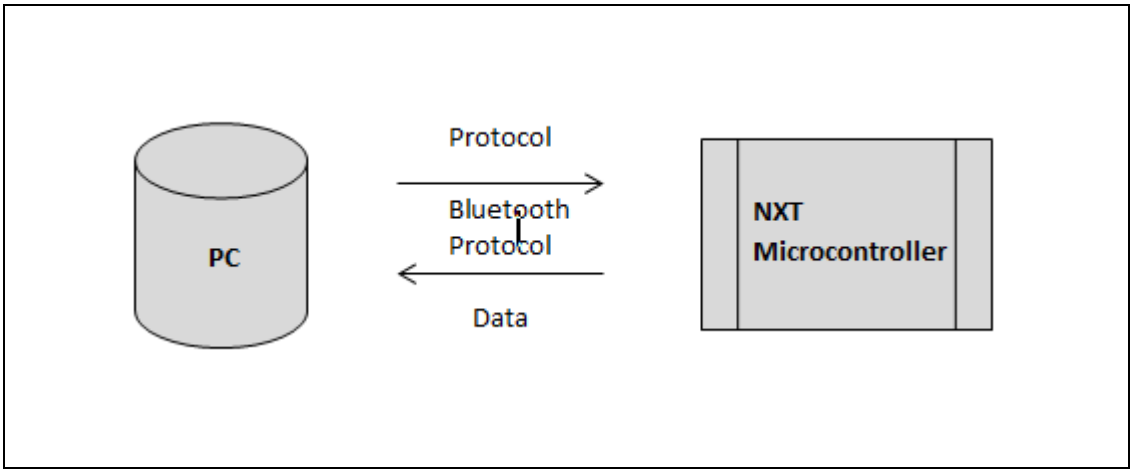


FIGURE 3.5: Communication Architecture

3.4 Development Methodology

The chosen development methodology for this project is throwaway prototyping. It is a methodology that has a relatively thorough analysis phase that is used to gather information and to develop ideas for the concept of the system, as shown in Figure 3.6. Each of these issues is examined by analysing, designing, and building a design prototype. A design prototype is not a working system but it is a product that represents a part of the system that needs additional refinement and it contains enough detail to enable users to understand the issues under consideration.

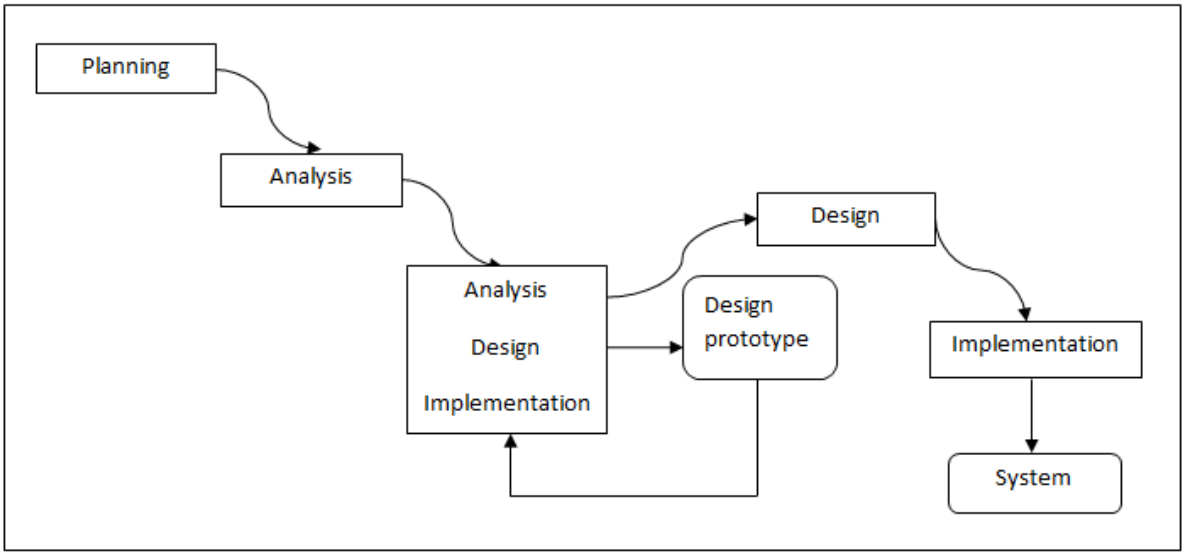


FIGURE 3.6: System Methodology

A system developed using this type of methodology relies on several design prototypes during the analysis and design phases. Each of the prototypes is used to minimize the risk associated with the system by confirming that important issues are understood before the real system is build. Once the issues are resolved, the project moves into design and implementation. At this point, the design prototypes are thrown away. This creates an important difference between these methodologies and prototyping methodologies, in which the prototypes evolve into the final system. Throwaway prototyping based methodologies balance the benefit of well thought out

analysis and design phases with the advantages of using prototypes to refine key issues before a system is build.

There are many advantages using this type of methodology. The advantages is the reduced time and cost. This prototyping can improve the quality of requirement and specifications provided to developers. Because changes will be more costly to implement as they are detected later in development, the early determination of what user really want can result in faster and less expensive. Other advantage is improved and increased user involvement as this prototyping requires user involvement and allows them to see and interact with a prototype, allowing them to provide better and more complete feedback and specification. The presence of the prototype being examined by the user prevents many misunderstandings and miscommunications that occur when each side believe the other understands what they said. Since users know the problem domain better than anyone on the development team does, increased interaction can result in final product that has greater tangible and intangible quality. The final product is more likely to satisfy the user desire for look, feel, performance and also too reduced development time.

3.5 Project Activities

As per mentioned in the previous section, the main project phases of activities will be divided into five sections which are:

1. Planning Phase
2. Analysis Phase
3. Prototype Phase
4. Design Phase
5. Implementation Phase

The activities breakdown for each phase is stated in the Gantt Chart in the Section 3.6. Up until December 2013, the project has reached the design phase which will be continually developed and improved on month onwards. Besides, the project will be continued with the implementation phase where the program of Book Sorter is developed. During that time, the design will be adjusted accordingly to the feasibility of its operation.

3.6 Key Milestone

Referring to the project activities, the key milestone of this project is shown in figure 3.7:

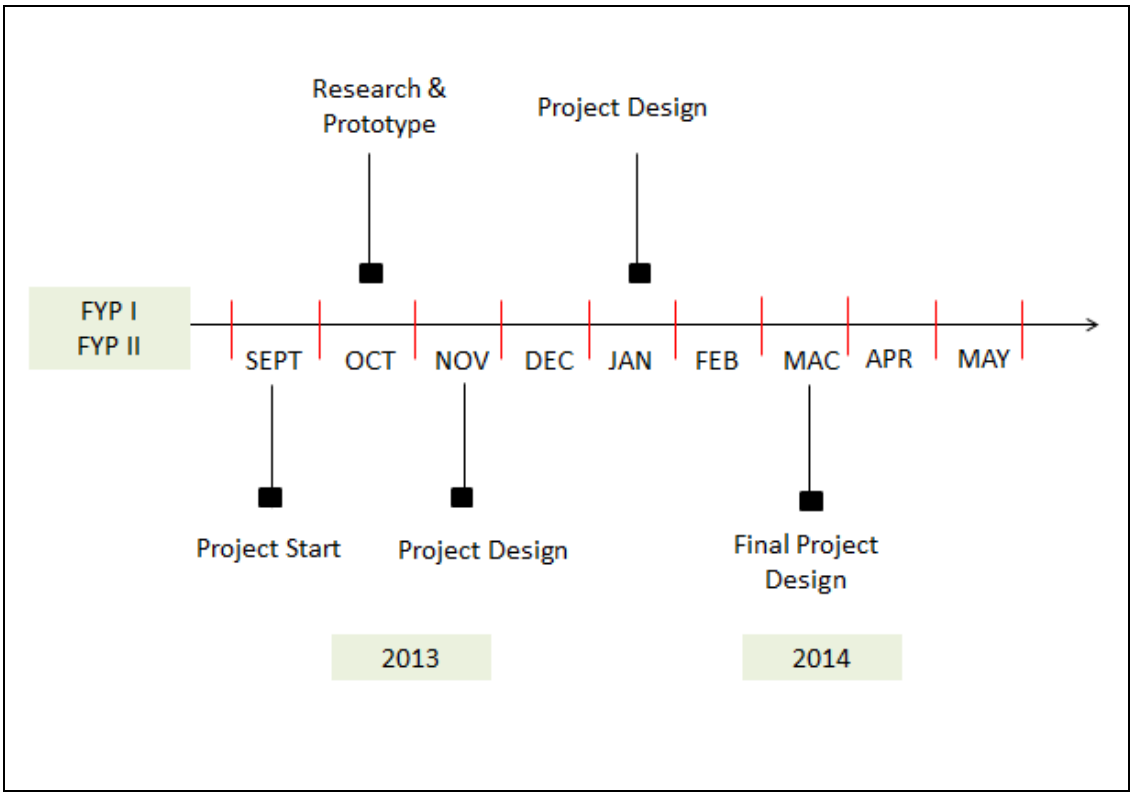


FIGURE 3.7: Key Milestone

3.7 Gantt Chart

TABLE 3.1: Gantt Chart

PHASE/PERIOD (MONTH/2013-2014)	SEPT 2013		OCT 2013				NOV 2013				DEC 2013			JAN 2014		FEB 2014				MAC 2014				APR 2014			
PERIOD (WEEK)	1	2	3	4	5	6	7	8	9	10	11	12	13	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Planning - Brainstorming - Area Proposal - Project's Title Submission																											
Analysis - Research Development - Literature Review - Extended Proposal																											
Prototype - Sketch Design/Blueprint - Proposal Defense and Progress Evaluation																											
Design - Data Analysis and Collection - Robot Development - Interim Report																											
Implementation - Program Development (Code) - Progress Report (6/2)																											
System - Testing - Pre-SEDEX (2/4) - 1st Draft Dissertation (8/4) - Technical Report (10/4) - Final Dissertation (10/4) - VIVA (23/4)																											

3.8 Tools Used

The list of tools required in order to complete this project are described in Table 3.2:

TABLE 3.2: Tool's Description

No	Tools	Description
1	LEGO Mindstorm NXT 2.0 kit	Provide the core set for the robot development: - NXT Educational Software - Interactive Servo Motors (rotation sensor) - Sensors - Rechargeable DC Battery - Intelligent NXT Brick with cables - Others LEGO elements
2	Ultrasonic Sensor	To sense proximity (distance)
3	Color Sensor	To detect color
4	Light Sensor	To use for line tracking (contrast)
5	Personal Computer (PC)	To install the NXT software (stated above) to develop program for the robot and also used for research and documentation
6	Microsoft Word	Write-up production
7	Microsoft PowerPoint	Presentation purpose e.g. Viva/Proposal defense
8	Programming Language	LabVIEW and NXC, a C-like high level programming language. Suit the program that contains many loops.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

In having a more reliable project and ultimate acceptance of the prototype, there are several interviews and testing has been carried out. They are:

1) Interview (FYP I)
2) Survey and Feedbacks (19 March 2014)
3) Field test (28 March 2014)
4) Acceptance Testing (31 March 2014)

The information is gathered and collected. The final decision is made upon the comparative study of that information; originated from different sources of study.

4.2 Results of Interview

TABLE 4.1: Interview Itinerary

Date/Time	FYP I Semester
Venue	UTP Library / Information Resource Centre
Interviewee	Mr Faris Syahmi
Position of Interviewee	Staff of sorting group

The interview was held to investigate on how they carried out the book sorting process. It is mainly about the time taken, number of labours used, total number of books to be sorted and workload in daily context. The information is collected and tabulated. Then the data is analysed and represented in the pie and bar chart as per shown below:

The total time taken for sorting a trolley of books in one level is one (1) hour. As illustrated in Figure 4.1, 50 percent of the period is allocated for sorting the books at the circulation desk. Staffs that are in charges of book sorting will come to the trolley and sort the book according to their level and shelves. Apart from that, another 25 percent of the time is used for taking the trolley of sorted books to the respective level. When the trolley is already at the right level, placing the books requires the last 15 minutes that is equivalent to 25 percent of 1 hour period.

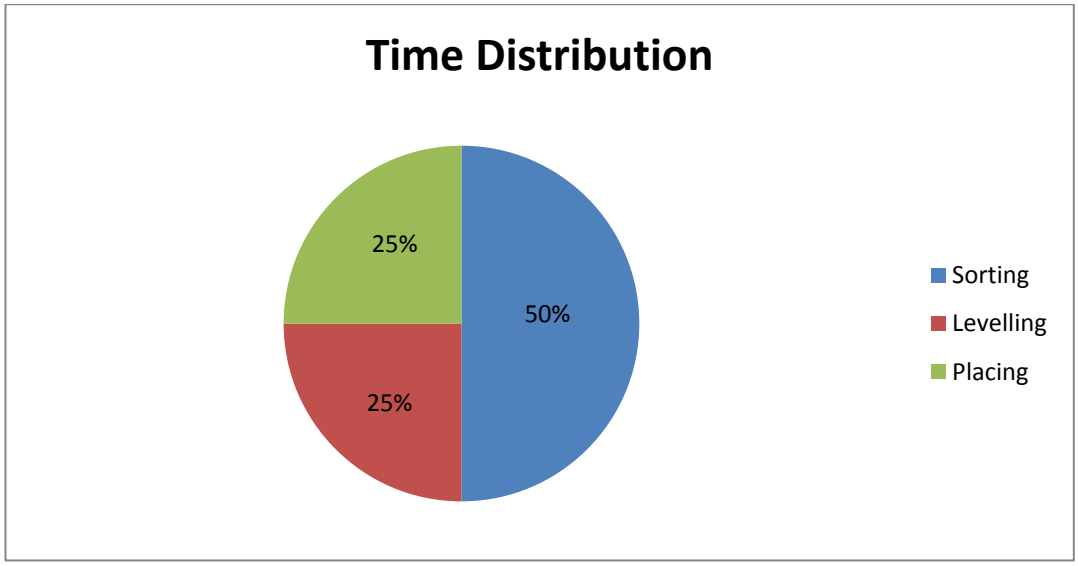


FIGURE 4.1: Time Distribution

The interview resulted in information that the book sorting group consists of 5 labours who are working in shifts. There are two working shifts; morning (8.30am-10.30am) and evening (1pm-3pm). As seen in Figure 4.2, 60 percent of total labours are allocated for morning shift and the remaining 40 percent at the evening shift. It shows that there are 3 trolleys that will be sorted in the morning while another 2 trolleys of books are going to be processed in the next shift. According to this information, it can be concluded that one labour is responsible for one trolley.

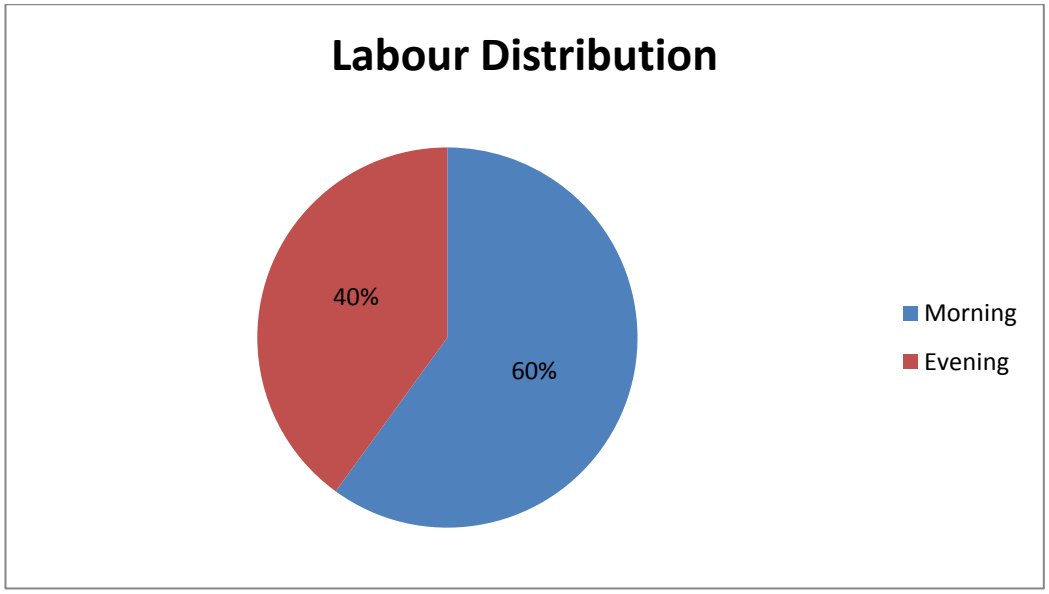


FIGURE 4.2: Labour Distribution

As with book distribution, the books are fairly distributed into 5 levels; level G, level 1, level 1m, level 2 and level 2m. This distribution is shown in Figure 4.3. The fair distribution means that every trolley is sorted into its level where each trolley is actually belong to one level only. The number of books is varied due to the seasonal factor as per discussed in Figure 4.4.

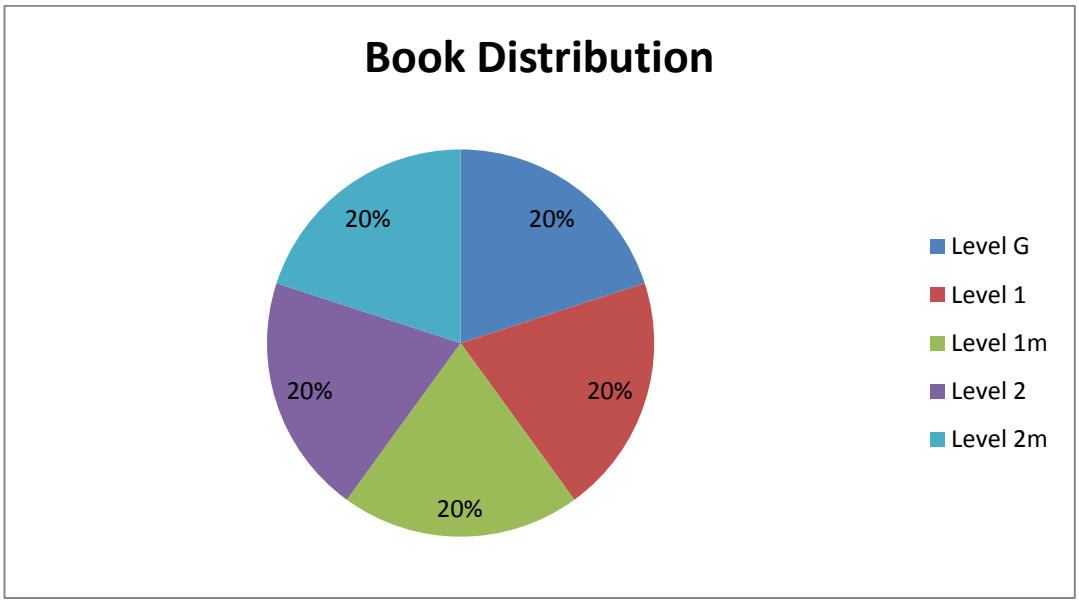


FIGURE 4.3: Book Distribution

Just in one day, there are a lot of books that are required for sorting process. However, as suggested by Figure 4.3, the total number of books is varied according to the respective weeks. The staff categorized a semester into 3 phase, early (week 1-5), middle (week 6-9) and end (Week 10-14) of the semester. Based on figure 4.4, the number of books is increasing towards the end of the semester due to the seasonal factor e.g. project's submission and examination period. In the early phase of semester, there are 500 books are returned by the students daily and if it is divided into levels, the labour only has to sort 100 books per level. It keeps increasing to 750 and it is approximately 1000 books counted in one day starting from week 10 to week 14. It defines that one labour is subjected to sort 200 books in one level daily.

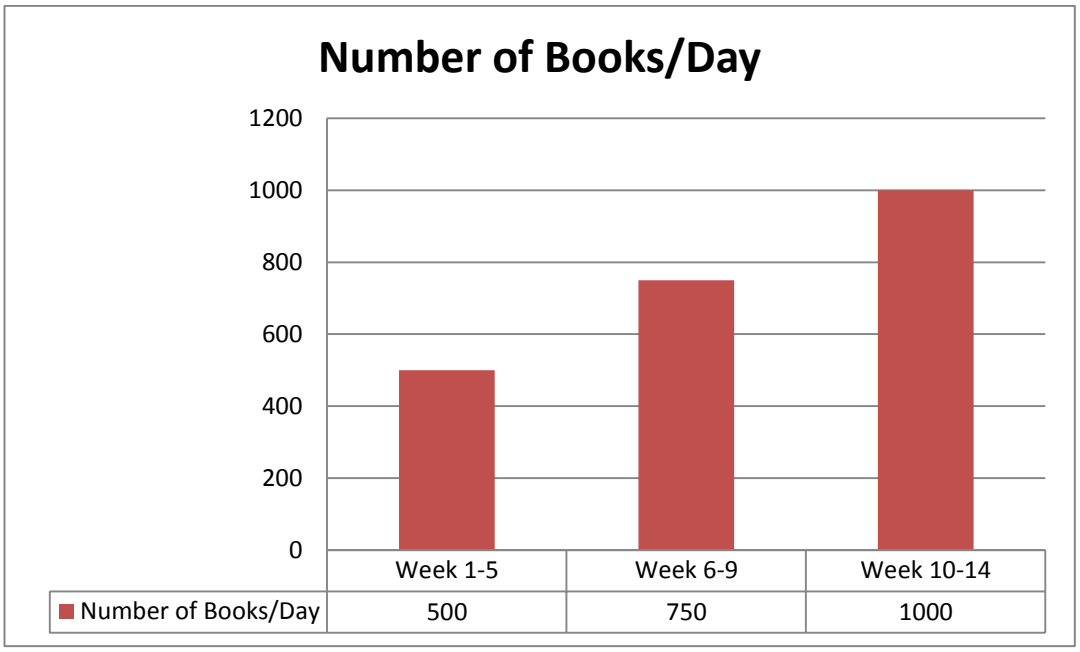


FIGURE 4.4: Number of Books

4.3 Results of Survey and Feedbacks

TABLE 4.2: Survey Itinerary

Date/Time	Wednesday, 19 March 2013
Venue	Virtual Laboratory, Block 02
Respondents	80 Secondary Students
Age Range of Respondents	16 to 17 Years Old
Photo	 

The survey was distributed among 80 secondary students from Sekolah Menengah Kebangsaan (SMK) Jelai, Taiping Perak. The problems, objectives and functionality of the system are briefly explained prior to the demonstration. After that, the demonstration of the system is carried out and followed by handing in a set of

questions for every student. The results of the survey and feedbacks are tabulated and illustrated in the charts below:

Based on the survey conducted, Figure 4.5 categorized as 80 students of secondary school are mostly aware of Artificial Intelligence (AI). 45 % of the students are strongly agreed that they know AI. It indicates that the students know that AI is part of Information and Communication Technology (ICT) that is closely related to robotics application.

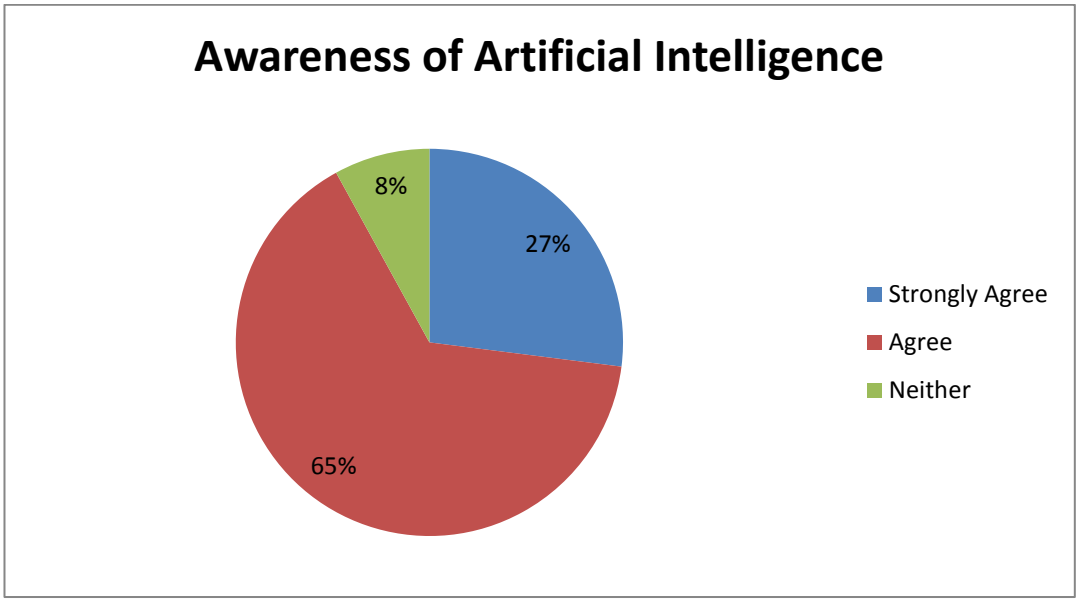


FIGURE 4.5: Awareness of Artificial Intelligence

Besides that, part of the survey emphasised on the design of prototype. 100 % of respondents are agreed that the design of Book Sorter is attractive. In fact, 55 % of them are strongly connotes the design of the system is attractive as a whole. Lego Librarian received a good attention and feedback from the students.

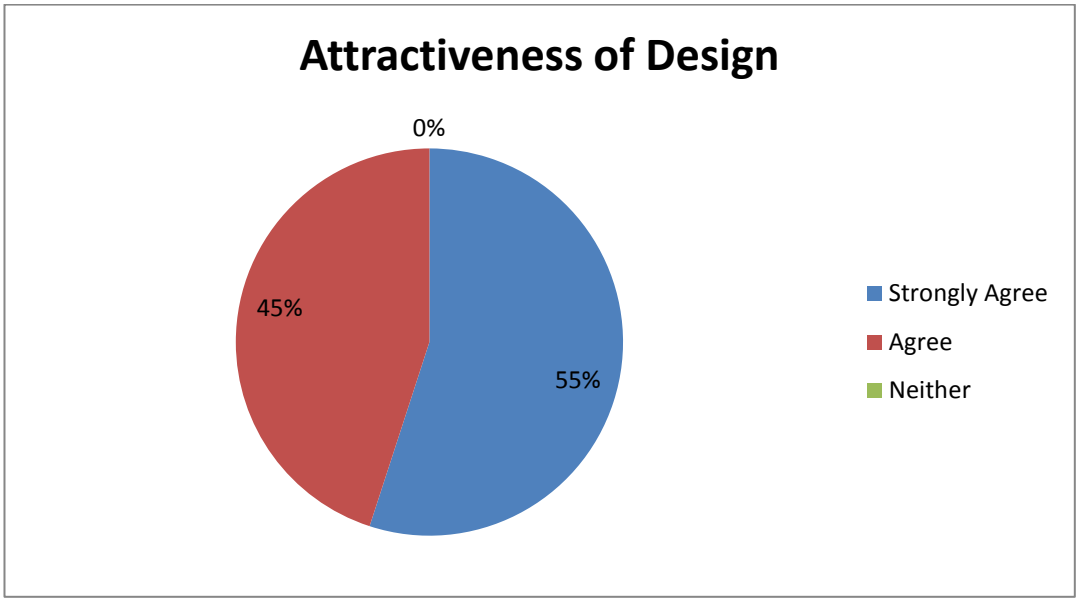


FIGURE 4.6: Attractiveness of Design

On the other hand, the survey needed the respondents to give feedbacks on its functionality. It has been asked whether Lego Librarian is useful and helpful for human in the aspect of library management system. 56% of the respondents are strongly agreed that the system is useful to be implemented in the library. Another 40% of respondents are fairly agreed while the remaining ones are neither agree nor strongly agree.

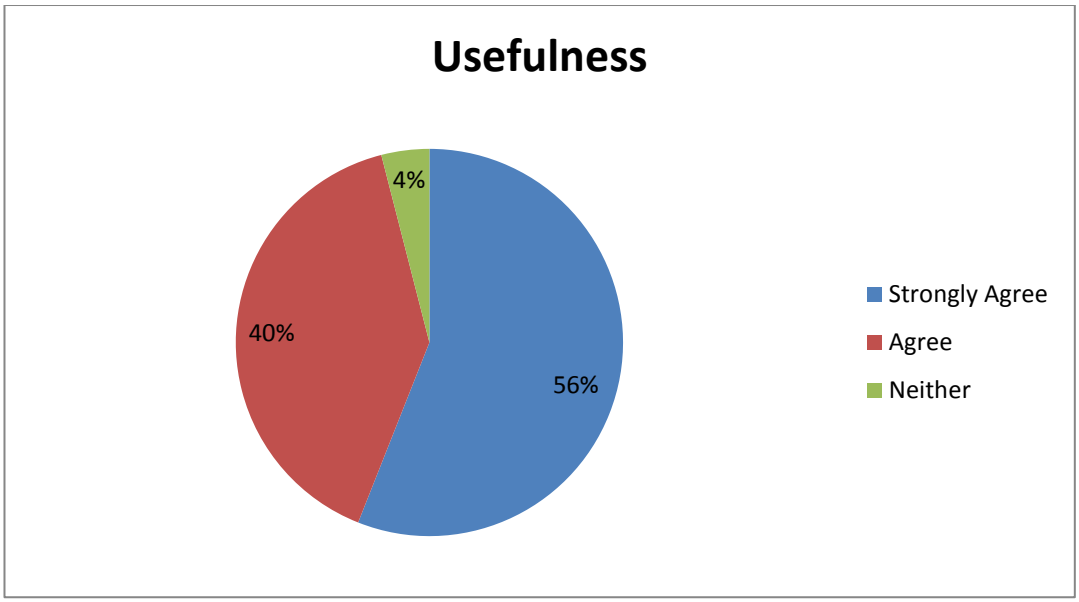


FIGURE 4.7: Usefulness

The last part of the survey was assessed the system in term of alternative used. Based on the results obtained for this section, manufacturing (37%) and restaurant (35%) received the most votes as an alternative industry, where Lego Librarian should be implemented at. Another 19% are agreed that house can also be an alternative industry for this system and the remaining 9% goes to hospital. This result indicates that this system is well potential and will be able to achieve good market position if it is been commercialized.

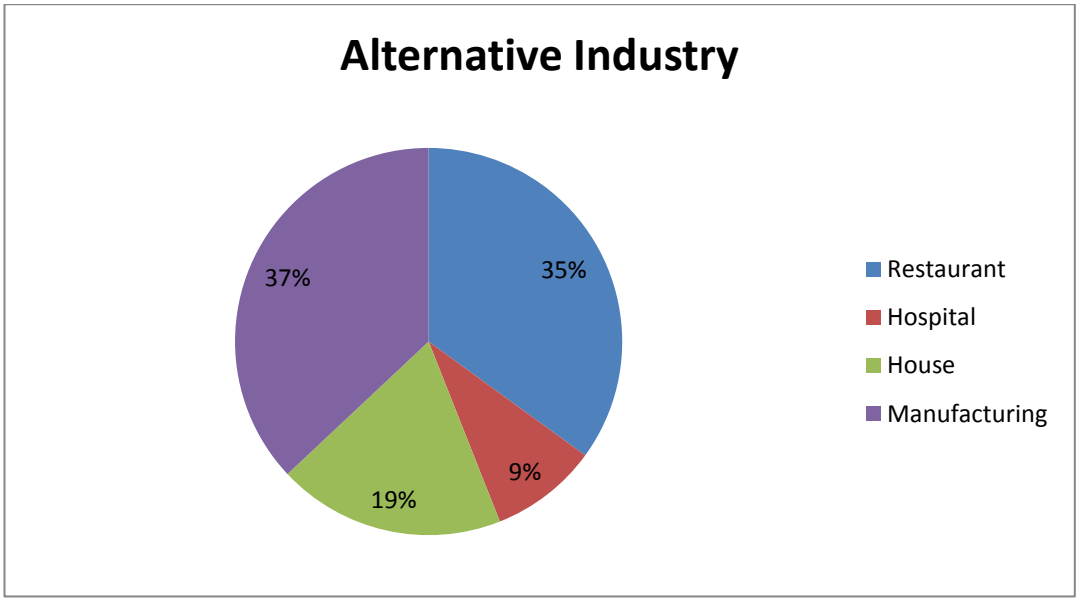
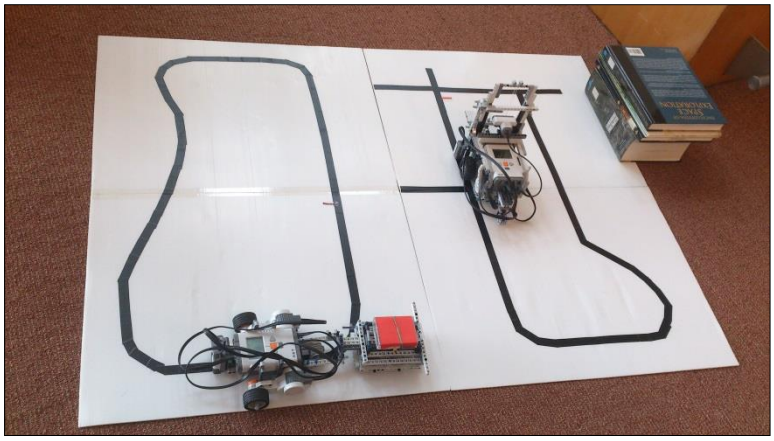


FIGURE 4.8: Alternative Industry

4.4 Results of Field Test

TABLE 4.3: Field Test Itinerary

Date/Time	Friday, 28 March 2014
Venue	UTP Common Room, Village 3-C
Attendee	Ms Thulasi Palakrisnan, Book Carrier Developer
Photo	

The field test was held three days before conducting acceptance testing. It is aimed to have a valid specification for the prototype significantly for the demonstration among the attendees during the acceptance testing. The limitation on its specification is collected and tabulated. The results of field test are discussed below:

The first test conducted was surface test. It tested Book Sorter on two type of surface; smooth and rough. The smooth type used white corrugated board and the carpet was used for the rough type. The distance was fixed to 1 metre and the time taken for the robot moving across such distance was recorded. Table 4.4 has resulted in the fastest speed belongs to the smooth surface type with the speed of 0.130 metre per second.

TABLE 4.4: Surface Test

Surface Type	Distance (m)	Time Taken (s)	Speed (ms^{-1})
Smooth	1	7.70	0.130
Rough	1	8.50	0.118

Second, a line test took place. The Book Sorter was tested on two type of lines; straight and curvy. The surface type was fixed to smooth and the distance was also made constant to 1 metre. The time taken needed for the robot to move across both type of the lines are recorded. At last, the speed was calculated for each trial. From the test, Book Sorter moved faster on curvy line with the speed of 0.137 metre per second rather than moving on the straight line. Based on Table 4.5, the speed difference is 0.007 ms^{-1}.

TABLE 4.5: Line Test

Line Type	Distance (m)	Time Taken (s)	Speed (ms^{-1})
Straight	1	7.70	0.130
Curvy	1	7.30	0.137

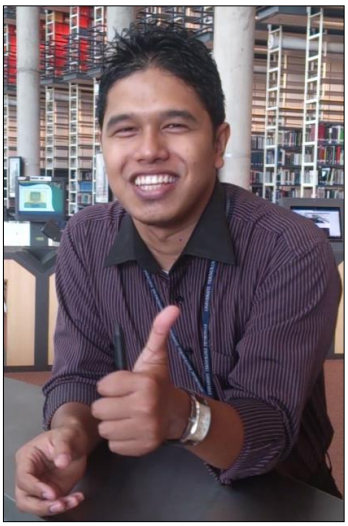
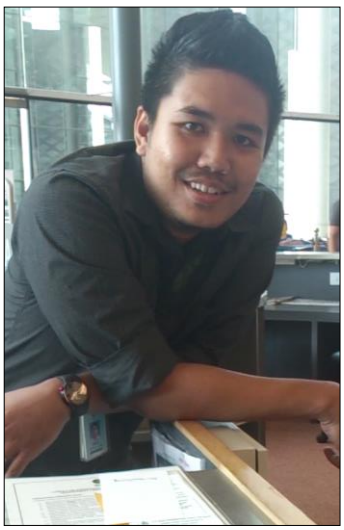
Lastly, weight test was conducted. The distance was fixed to 1 metre and the different weight of load was used as a test case. The time taken was recorded for 3 trials. Based on the result gained and tabulated in Table 4.6, the maximum load the Book Sorter can brought is 70 gram with the speed of 0.085 metre per second. The speed is getting higher when the weight of the load is reduced.

TABLE 4.6: Weight Test

Distance (m)	Load (g)	Time Taken (s)	Speed (ms^{-1})
1	10	8.01	0.125
1	50	9.80	0.102
1	70	11.76	0.085

4.5 Results of Acceptance Testing

TABLE 4.7: Acceptance Testing Itinerary

Date/Time	Monday, 31 March 2014
Venue	UTP Library / Information Resource Centre
Interviewee	5 of UTP Library Staff
Position of Interviewee	Staff of sorting group, shelving and circulatory desk
Photo	   

The acceptance testing was done among the staffs of UTP Library as they are the most suitable candidates to test this system due their jobs' scope in library management system. They are working closely related with book's collection and sorting. From the demonstration conducted during the testing, there are some pros and cons for the system received from the staffs. The data are tabulated.

TABLE 4.8: Pros and Cons of Prototype

Pros	Cons
Attractive design	The implementation of the cable is inconsistent
Good collaboration of Book Sorter and Book Carrier	High cost needed if it is going to undergo real implementation in the library
Able to save human energy	-
Able to save time for sorting task	-

4.6 Development of Book Sorter

Up until December 2013, the Book Sorter (BS) has been assembled using the LEGO Mindstorms Kit 2.0. As illustrated in Figure 4.9, there are different views are captured to ensure the design details are correct according to the design plan as per explained in Table 4.9.

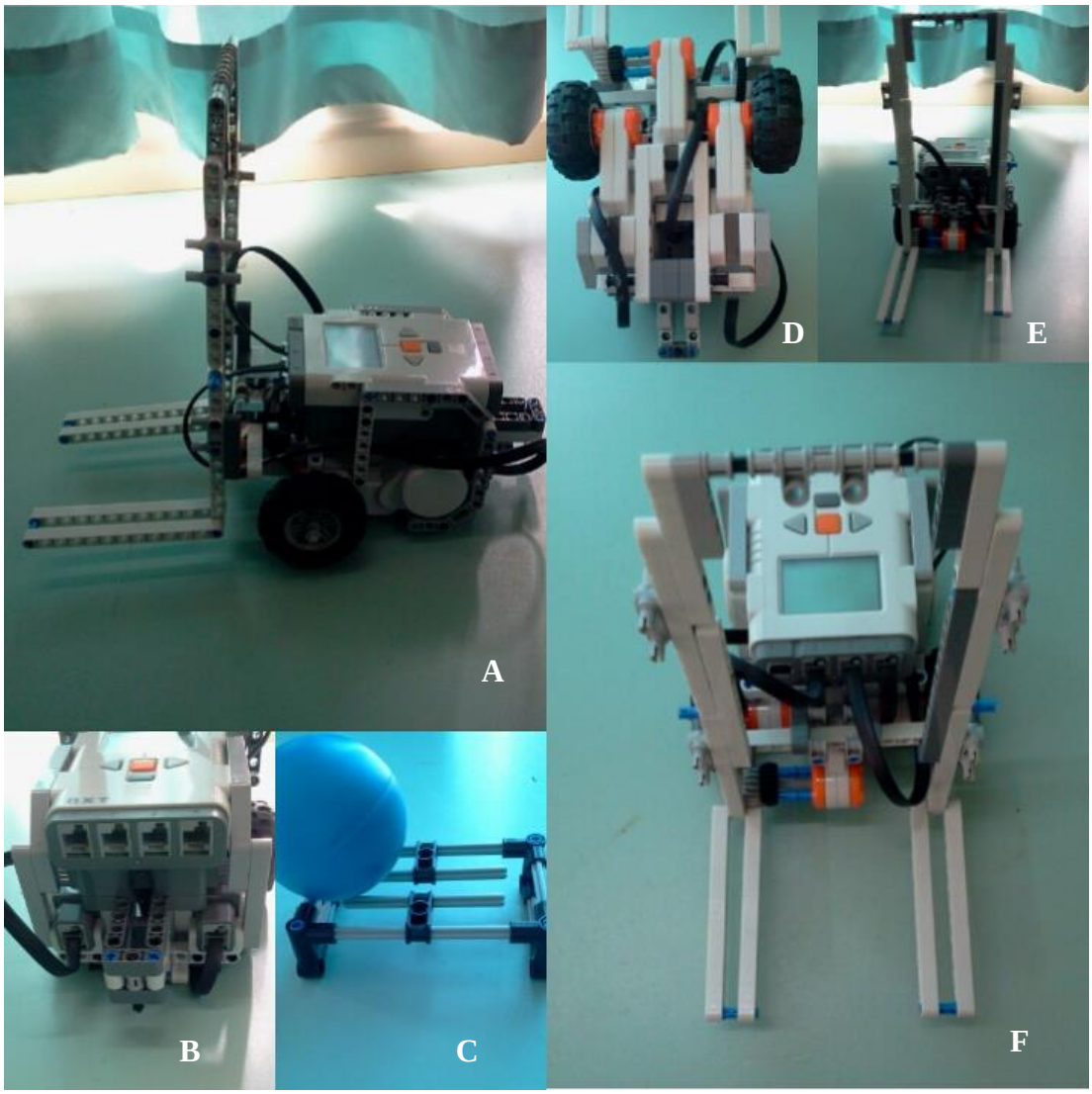


FIGURE 4.9: Book Sorter Design

TABLE 4.9: Design's Description

Picture	Description
A	Side View Consists of two parts; forklift and body. The body of BS is made up of a microcontroller that acts as CPU of the whole system. The programmable code will be installed within the microcontroller.
B	Back View There are number of available ports at the microcontroller. It will be used to connect the microcontroller to the sensors; ultrasonic, color and light sensor. Some of the ports have been used to connect the motor.
C	Lifting Rack The lifting rack is designed to ease the lifting process. As of the forklift works with its two hands, it will be easier if it can lift the rack that consists of object instead of lifting the object only.
D	Bottom View BS is designed to have 3 motors and each of the motor is connected to the tyre. They have their own embedded rotation sensor that has counter to control the turning.
E	Front View It shows the design of the forklift. The height of the forklift that can lift up and down is specified to 15cm yet it is adjustable based on the development (programming) phase where it can be tested and adjusted according to the height of shelf.
F	Plan View The view on top of BS.

As of January 2014, Book Sorter has been improved in term of its design in order to fit with its functionalities. The latest design of book sorter is shown below:

1) 3 motors chassis

Only two tyres are attached to two motors provided. Another tyre at the back of the robot is not controlled by any motor yet it is designed to be flexible that will ease the turning mechanism of the robot. It will simply react accordingly to where the two front tyres are heading to. Another motor is used to control the lifting mechanism of the robot. The architecture of this design is shown in Figure 4.10.

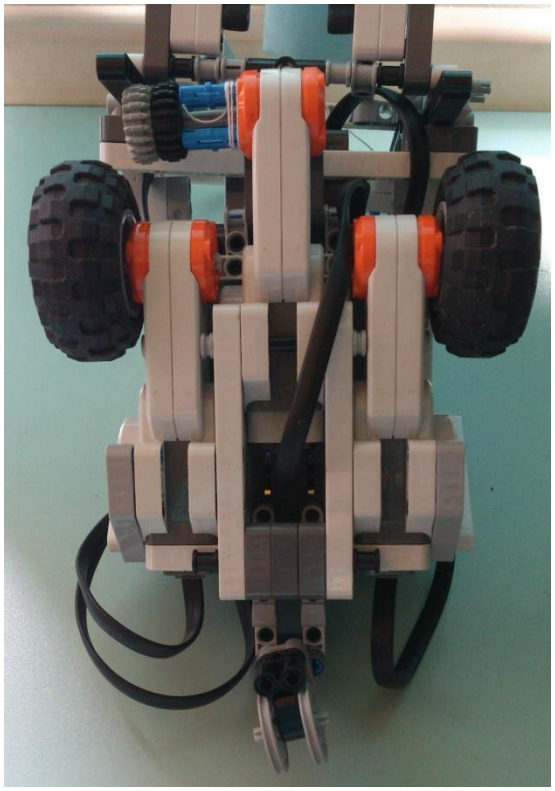


FIGURE 4.10: Chassis

2) 50cm string attachment

As seen in Figure 4.11: The book sorter is equipped with 50 cm string on the lifting mechanism. The string is tied on the motor responsible of controlling the lifting and joined to the fork by passing the upper part of robot. The ups and downs movement of the fork are affected to the length of the string and rotation number of motor.

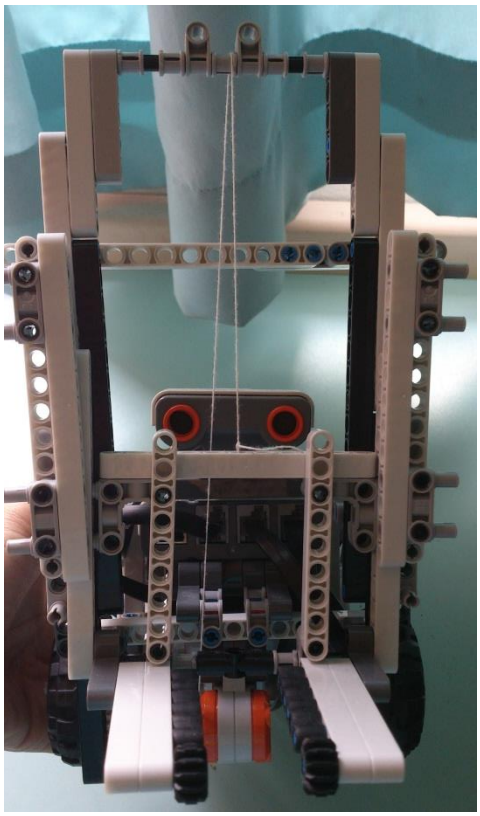


FIGURE 4.11: Lift

As of March 2014, the Book Sorter is capable of moving on track by following the black tape on a white corrugated board. Book Sorter is built associated with a line track as per shown in Figure 4.12. The track is drawn for having a clear simulation for the small-scale prototype. The colour strips are pasted just right beside the black line where the robot is supposedly to follow. The track is purposely drawn in a combination of straight and curvy line to test the capability of the robot. As a completion for the Lego Librarian system, Book Carrier is shown just right beside the track simulation of Book Sorter.

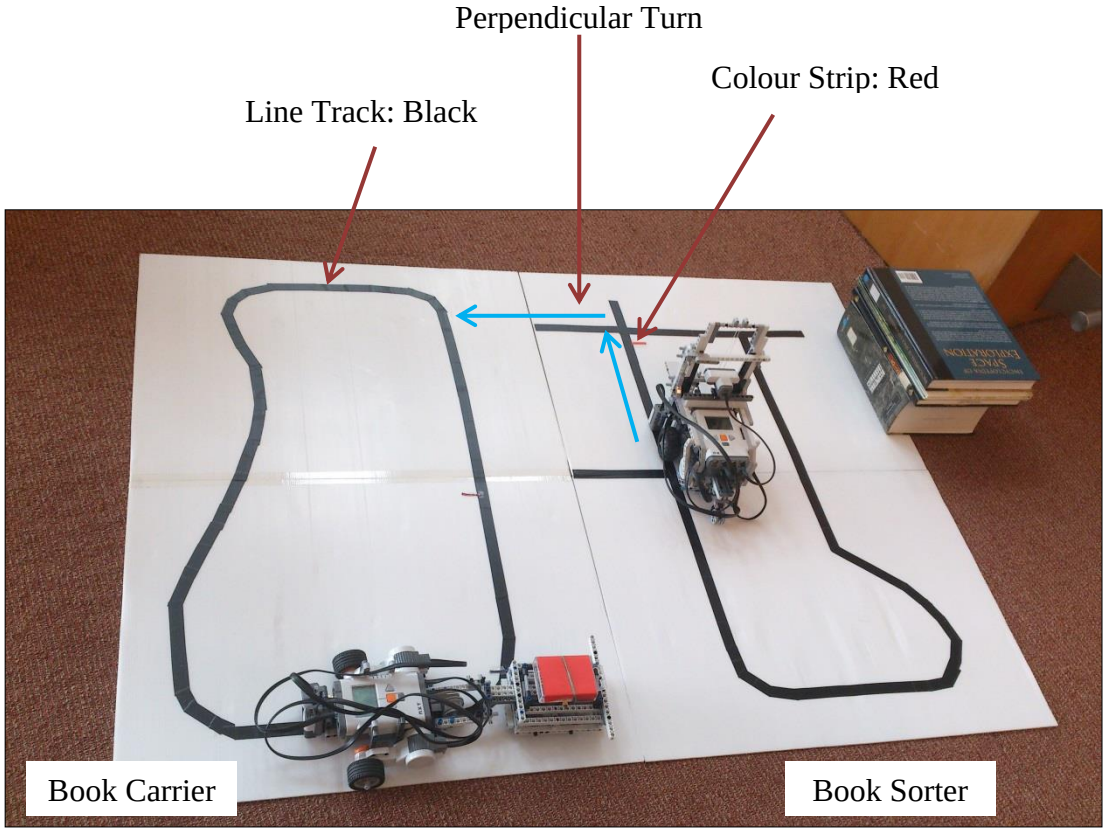


FIGURE 4.12 Line Track

The final representation of Book Sorter is presented in Figure 4.13. This finished prototype is equipped with two (2) colour sensors, one (1) ultrasonic sensor, and three (3) motors.

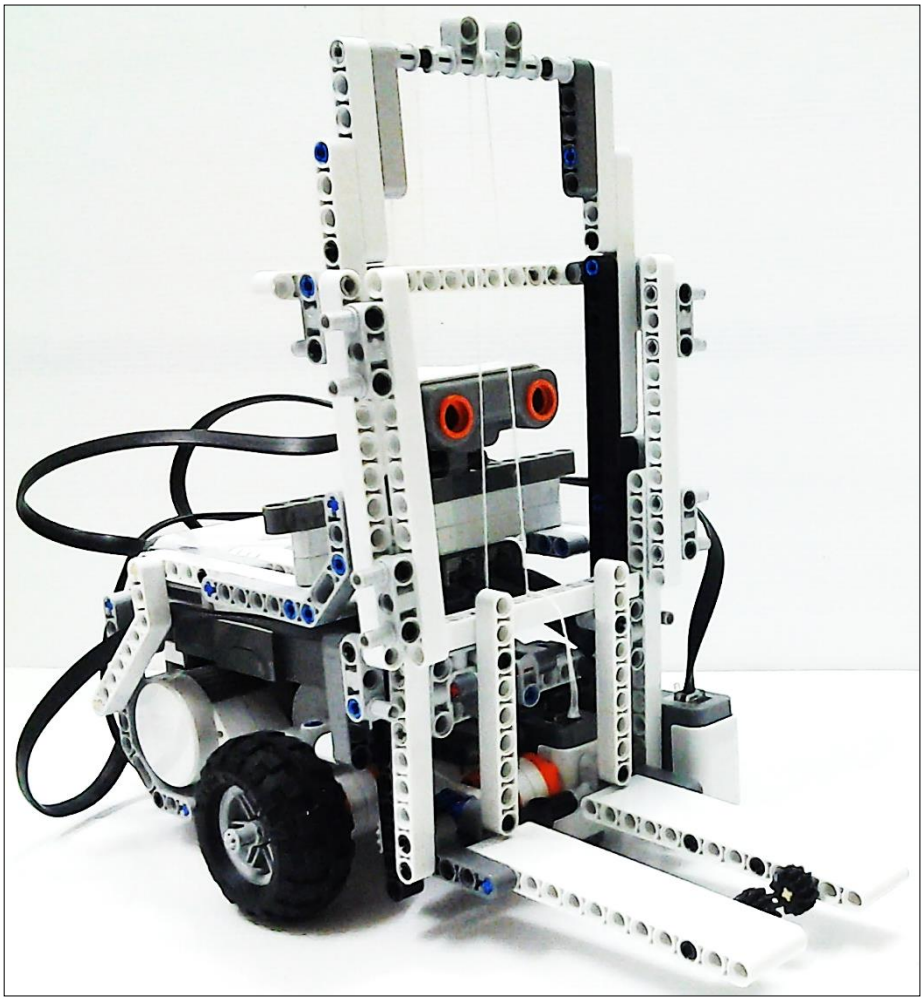
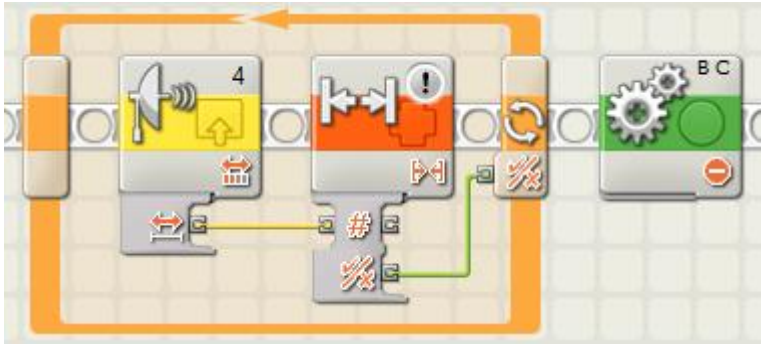
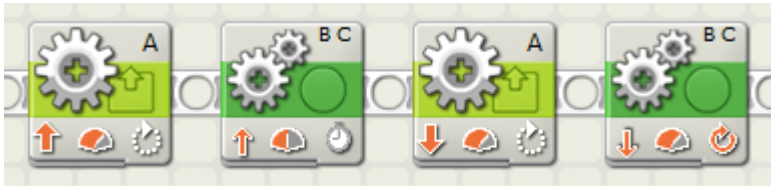
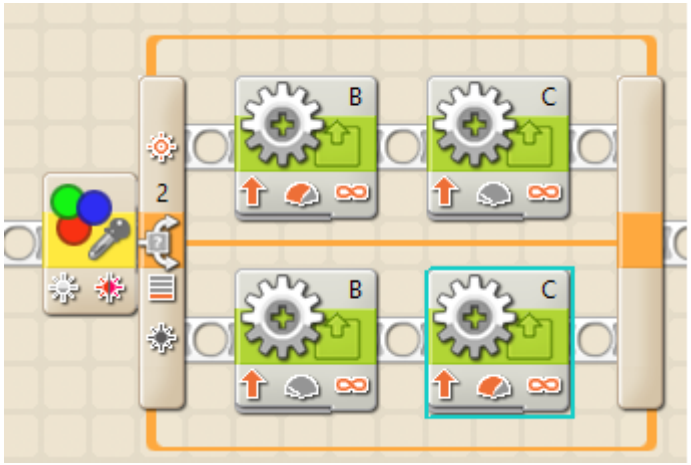


FIGURE 4.13 Finished Prototype

In addition, the modules that have been programmed for book sorter are explained in Table 4.10:

TABLE 4.10: Code's Description

No	Mechanism	Code	Action
I.	Object Detection	A: Detect the platform by using ultrasonic sensor 	- It is a loop for the robot to keep moving forward until it sees something between 14 to 16 cm away - Stop when the right distance towards the platform is found
II.	Object Lifting	B: Lift the load off the ground 	- Book Sorter drives forward to get the load - Raise the lift to get the load off the ground - Moves forward to reach the platform. The duration is set to unlimited because the robot is programmed to use ultrasonic sensor in finding the platform - The fork is raised of the way up

		C: Lift the load onto the platform  	- Keeps moving slowly towards the platform until BS hits it - Lower the fork to place the load on the platform - Back up a little to get away from the platform - The maximum height that it can lift up load is 15 cm
III.	Line Following	D: Line following  	- The colour sensor is programmed to follow black colour only - The power of each motor responsible for each tyre is different - In order for the robot to be back on the track if it is happened to deviate from the track, the power need to be different due to its balance

CHAPTER 5

CONCLUSION

In this project, a book sorting robot namely, Book Sorter is a small scale robot developed as a simulation of potential application to ease up the daunting tasks of human librarians. The details and requirement of the project has been briefly discussed. It includes an abstract to the project, project introduction, problem statement and objectives. The study has been leveraged by writing a literature review on this particular research. Besides, it comes along with UML analysis; activity diagram to reveal the feasibility of the proposed system. The initial until the final design of Book Sorter system is attached in Chapter 4 as well as its block diagram.

Additionally, the results from the interview, survey, field test and acceptance testing are well discussed in Chapter 4. An unmanned Book Sorter has successfully built and the Lego Librarian system is completed. The development is done to prove the concept of forklift system for book sorting management in library. The small (lab) scaled robot has the ability to carry a maximum of 70 gram of loads for a minimum of one (1) meter distance on both straight and curvy line and stops at the right location to reach book carrier based on colour detection. The maximum height it can raise the load is 15 centimetres. From the results obtained, it satisfied the specific objectives of this project which to investigate object scanning, lifting and sorting process. The Book Sorter has been tested for these three processes. Furthermore, it also met another specific objective which this project is successful to develop a robot capable of scanning and picking the book from the book carrier onto the shelves.

In term of the project reusability, other than the library, the proposed research can also be applied to other areas such as manufacturing company, restaurant and house. From the survey and feedbacks conducted, it is proved that the project is potentially to be applied in a bigger scale of work and will be able to have a good market position if it is commercialized. Lastly, the project is recommended to have a flexible lifting which has no limitation on the height of shelf.

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APPENDICES

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

(please state): _____

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

☐ House ☐ Manufacturing Companies ☐ Hospital
☐ Restaurant ☐ Others (please state): _____

3. Any suggestion for future improvements of Lego Librarian?

☐ Yes
☐ No (please state):

_____

_____