REPORT DECLARATION LETTER (OPTIONAL)

Librarian,
Perpustakaan Universiti Malaysia Pahang,
Universiti Malaysia Pahang,
Lebuhraya Tun Razak,
26300, Gambang, Kuantan.

Dear Sir,

CLASSIFICATION OF THESIS AS RESTRICTED

Please be informed that the following thesis is classified as RESTRICTED for a period of three (3) years from the date of this letter. The reasons for this classification are as listed below.

Author's Name
Thesis Title

Reasons (i)

(ii)

(iii)

Thank you.

Yours faithfully,

_____
(Supervisor's Signature)

Date:

Stamp:

Universiti Malaysia PAHANG
Engineering • Technology • Creativity

SUPERVISOR'S DECLARATION

We hereby declare that we have checked this report and in my opinion, this report is adequate in terms of scope and quality for the award of the degree of Bachelor of Engineering in Mechatronics.

(Supervisor's Signature)

Full Name : EN.ISMAIL BIN MOHD KHAIRUDDIN

Position :

Date :

(Co-supervisor's Signature)

Full Name : DR. AHMAD SHAHRIZAN BIN ABDUL GHANI

Position : Lecturer

Date : 8 JUNE 2017

Universiti Malaysia PAHANG
Engineering • Technology • Creativity

STUDENT'S DECLARATION

I hereby declare that the work in this report is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

(Student's Signature)

Full Name : YONG ZONG WEI

ID Number : FB13053

Date : 8 JUNE 2017

USING MYRIO

YONG ZONG WEI

Report submitted in partial fulfillment of the requirements
for the award of the degree of
Bachelor of Engineering (Hons.) Mechatronic Engineering

Faculty of Manufacturing Engineering
UNIVERSITI MALAYSIA PAHANG

JUNE 2017

ACKNOWLEDGEMENTS

First and foremost, I would like to thanks to god for providing me strength and blessings to complete this thesis and finish my project on time. This project would not be able to complete if without any help for the people around me.

Next, I am grateful and would like to express my sincere gratitude to my supervisors En.Ismail Bin Mohd Khairuddin and Dr. Ahmad Shahrizan Bin Abdul Ghani for providing me an opportunity to work with them. Without their germinal and helpful idea yet offered an invaluable assistance, this project will not be able to successful complete. Besides, they had always impressed me with their professional conduct their strong conviction for success.

Other than that, I would like to thank all my friend who helped me in this project. They provided me very useful idea and help me whenever I am facing trouble and giving me moral support.

Last but not least, a special thanks to my parents for the moral support and some financial support to help me throughout this project. Their endless love give me a lot of energy to complete my thesis.

ABSTRAK

Kajian penyelidikan menunjukan robot mudah alih autonomi dan banyak kajian dijalankan untuk mengurangkan kerja-kerja manusia dan memudahkan kerja. Dalam penyelidikan, robot mudah alih amat berguna untuk manusia kerana bahaya dan batasan manusia mempunyai sebab utama keperluan untuk robot mudah alih yang lebih serba boleh dan berkuasa, terutamanya dalam industri pemesinan dan pengkalan tentera. Selain itu, reka bentuk yang stabil untuk robot mudah alih boleh mudah untuk bergerak dalam alam sekitar. Selain itu, navigasi dan halangan objek juga digunakan peguam dalam robot mudah alih. Dalam projek ini, kajian penyelidikan yang dijalankan untuk membangunkan algoritma robot mudah alih autonomi dengan pelaksanaan pemodelan dinamik menggunakan Newton-Euler approach.The jasad tegar daripada robot mudah alih dilengkapi dengan dua roda dan kastor untuk tujuan kawalan mudah dan stabil mengimbangi. Di samping itu, Kinect sensor gerakan akan digunakan untuk mengesan imej dan rakaman video semasa sensor ultrasonik mengelakkan halangan daripada robot mudah alih. Sebaliknya, simulasi mekanisme kawalan direalisasikan melalui pakej perisian LabVIEW mana pembangunan persekitaran robot mudah alih dijalankan dan dipindahkan ke perkakasan Instrumen Nasional Myrio. Keputusan mendapati bahawa robot mudah alih autonomi berjaya halangan dan merakam video semasa menggunakan kedua-dua sensor. Adalah dipercayai bahawa robot mudah alih ini boleh digunakan dalam persekitaran bahaya untuk merekodkan semua data penting yang memerlukan persekitaran mereka.

ABSTRACT

Current research show that autonomous mobile robot is being widely researched to reduce human work and ease the job. In the research, mobile robot very useful for human because hazards and human limitations have the main reason for the need for more versatile and powerful mobile robots, especially in machining industry and military bases. Besides that, stable design for mobile robot can easy to move in any environmental. Moreover, the navigation and obstacle the object also famous used in mobile robot. In this project, the research study is conducted to develop an autonomous mobile robot algorithm with implementation of dynamic modelling using Newton-Euler approach.The rigid body of the mobile robot is equipped with two wheels and a castor for the purpose of simple control and stable balancing. In addition, Kinect motion sensor will be applied for the image detection and video recording while ultrasonic sensor obstacle avoidance of the mobile robot. On the other hand, the simulation of the control mechanism is realized through LabVIEW software package where the development of the mobile robot environment is carried out and transferred to National Instrument myRIO hardware. Results found that the autonomous mobile robot successfully obstacle and record video while using both sensors. It is believed that this mobile robot can used in hazards environment to record all the important data that need those environment.

TABLE OF CONTENT

DECLARATION

TITLE PAGE

ACKNOWLEDGEMENTS ii

ABSTRAK iii

ABSTRACT iv

TABLE OF CONTENT v

LIST OF TABLES ix

LIST OF FIGURES x

LIST OF SYMBOLS xii

LIST OF ABBREVIATIONS xiii

CHAPTER 1 INTRODUCTION 1

1.1 Background Study 1

1.2 Problem Statement 3

1.3 Project Objective 3

1.4 Project Scope 4

CHAPTER 2 LITERATURE REVIEW 5

2.1 Introduction 5

2.2 Design and Develop an Autonomous Mobile Robot 5

2.2.1 Wheeled Mobile Robot (WMR) 5

2.2.2 Mathematical Modelling For Wheeled Mobile Robot 10

2.2.2.1 Kinematic Modelling 10

2.2.2.3 Dynamic Modelling 10

2.3 Microcontroller 11
2.3.1 Arduino 11
2.3.2 Raspberry Pi 12
2.3.3 NI-myRIO 12
2.4 Platooning Strategy 13
2.5 Sensor Technologies 13
2.5.1 Range Sensor 14
2.5.2 Visual Sensor 15
2.6 Summary 18

CHAPTER 3 METHODOLOGY 20

3.1 Introduction 20
3.2 Methodology Flow Chart 21
3.3 Hardware Development 22
3.3.1 Mechanical Development 22
3.3.1.1 WMR Design Using CATIA 22
3.3.2 Equipments 23
3.3.2.1 NI myRIO 23
3.3.2.2 Xbox 360 Microsoft Kinect Sensor Model 1414 24
3.3.2.3 DC Motor and Wheel 25
3.3.2.4 DC Motor Drive 26
3.3.2.5 Power Supply 27
3.3.3 Overall Hardware Structure 27
3.4 PID Controller 28
3.4.1 PID Theory 28
3.5 Model Development 30
3.5.1 Kinematic Model 30
3.5.2 Dynamic Model 33

3.5.2.1 Modelling for DC motor 34
3.5.2.2 Chassis Dynamics 35
3.5.2.3 Relationship between Motor Speed and Centre of Gravity for Chassis Movement (Kinematic) 38
3.5.2.4 Trajectory Calculation of the Arbitrary Chassis Points 39
3.5.2.5 Development the Overall Model and Steady-State 41
3.6 Kinect 45
3.6.1 Data Processing For Capture Image 45
3.7 Working Principle of the Mobile Robot 45

CHAPTER 4 RESULTS AND DISCUSSION 47

4.1 Introduction 47
4.2 Simulation and Results for WMR 47
4.2.1 Simulation Results 49
4.3 Result for Ultrasonic Sensor 53
4.4 Result for Kinect Sensor 54
4.5 Discussion 56

CHAPTER 5 CONCLUSION AND RECOMMENDATIONS 57

5.1 Conclusion 57
5.2 Recommendations 58

REFERENCES 59

APPENDIX A GANTT CHART 62

APPENDIX B LABVIEW SIMULATION FOR WMR 63

APPENDIX C LABVIEW SIMULATION FOR ULTRASONIC SENSOR 64

APPENDIX D LABVIEW SIMULATION FOR KINECT SENSOR 65

APPENDIX E CONFERENCE PAPER **66**

LIST OF TABLES

Table 2.1	Difference applications for each microcontroller	12
Table 4.1	Echo(μs) results	53
Table 4.2	Experimental parameter used	56

LIST OF FIGURES

Figure 1.1	Mobile robot types and application.	2
Figure 2.1	The four basic wheel classes	6
Figure 2.2	(a,b,c)Wheel configurations for rolling vehicles	9
Figure 2.3	Ultrasonic sensor working principle	14
Figure 2.4	Ultrasonic sensor in WMR	15
Figure 2.5	Skeleton joint element	16
Figure 2.6	Motion control the turning wheel	16
Figure 2.7	Two scenes typical of the captured data with Kinect.	17
Figure 2.8	Features in Kinect	17
Figure 3.1	Project flow chart	22
Figure 3.2	Design of mobile robo	23
Figure 3.3	NI myRIO platform	24
Figure 3.4	Xbox 360 Microsoft Kinect sensor	24
Figure 3.5	DC geared motor with Encoder SPG30E-30K	25
Figure 3.6	Plastic wheel for SPG30	26
Figure 3.7	SmartDriveDuo10 DC motor driver	26
Figure 3.8	LiPo Rechargeable Battery 11.1V 2200mAH	27
Figure 3.9	(a) Front view mobile robot, (b) Side view mobile robot	27
Figure 3.10	Process diagram for close loop system	28
Figure 3.11	Block diagram for a basic PID control alogrithum	28
Figure 3.12	The forward kinematic model	30
Figure 3.13	Reference frames for robot position	31
Figure 3.14	Equivalent circuit of motor	34
Figure 3.15	Scheme and forces for chassis	36
Figure 3.16	Angular speeds and linear recalculations	39
Figure 3.17	Arbitrary chassis point recalculation	40
Figure 3.18	Two DC motors wiring	41
Figure 3.19	Data processing for Kinect	45
Figure 3.20	Flow of the system	46
Figure 4.1	Encoder part in simulation	48
Figure 4.2	The user interface wall in LabVIEW simulation	48
Figure 4.3	The left wheel and right wheel velocity (rpm) and angular velocity	49
Figure 4.4	WMR motion respect to X and Y coordinate (straight line)	50

Figure 4.5	The left wheel and right wheel velocity (rpm) and angular velocity	50
Figure 4.6	WMR motion respect to X and Y coordinate (left direction)	51
Figure 4.7	The left wheel and right wheel velocity (rpm) and angular velocity	51
Figure 4.8	WMR motion respect to X and Y coordinate (right direction)	52
Figure 4.9	Top view for the obstacle result at 20 cm	54
Figure 4.10	Side view shown the mobile robot stop at 20 cm	54
Figure 4.11	User interface wall for Kinect sensor	55
Figure 4.12	Part of video record when mobile robot moving	55

LIST OF SYMBOLS

K_p	Proportional gain
K_i	Integral gain
K_d	Derivative gain
θ	Heading/ angle
X	Speed in x direction
ω	Angular velocity
Y	Speed in y direction
R	[Ω] resistance of the motor winding
L	[H] inductance of the motor
K	[kg.m2. s-2. A-1] electromotive constant
U_0	[V] voltage of the source
Ω	[rad. s-1] angular velocity of the rotor
i	[A] current flow in the winding
J	[kg.m2] moment of inertia
k_r	[kg.m2. s-1] resistance coefficient of rotation
M_x	[kg.m2. s-2] moment of the load
m	[kg] mass of the robot
k_v	[kg. s-1] linear motion's resistance coefficient
M_{GL}	[kg.m2. s-2] left drive's moment
M_{GP}	[kg.m2. s-2] right drive's moment
v_B	[m.s-1] speed of linear motion
r	[m] Wheel's semi-diameter.
l_P	[m] distance between point B and right wheel,
l_L	[m] distance between point B and left wheel,
l_T	[m] distance between centre of gravity and point B,
k_ω	[kg.m2. s-1] rotary motion's resistance coefficients
J_T	[kg.m2] MoI with respect to rotation axis in centre of gravity
ω_B	[s-1] angular speed in point B.
l_P	[m] distance between point B and right wheel,

LIST OF ABBREVIATIONS

WMR	Wheeled Mobile Robot
SoC	System on Chip
I/O	Input and Output
IR	Infrared
PID	Proportional-Integral-Derivation
SLAM	Simultaneous Localization And Mapping
MoI	Moment of Inertia
CMOS	Complementary Metal-Oxide- Semiconductor

CHAPTER 1

INTRODUCTION

This chapter mainly focuses on the general idea of this study along the project background, problem statement, project objectives and scope that covered on this project.

1.1 Background Study

Robotics had subdivided off the science that includes electrical engineering, manufacturing engineering, mechatronics engineering and others. As we know, robotics had attained a greatest successful in industrials on this world. There are many types of industrial applications using robotics such as the robot arm, mobile robots and other. The most popular robotics on this world is mobile robots. The hardware and software of mobile robot has been designed for the purpose of extreme environment, such that it will be able to perform their tasks in the presence of noise. In some cases where dynamic environment is involved, the mobile robot could not be able to perform good task such that the feedback from the robot is contradictory to the current situation being measured and inconsistent response information for a continuously changing environment.(Ali, 2011). Nowadays, mobile robots have been evolving to move automatically from one places to other locations. For daily activities, mobile robots have been extensively developed and researched to assist humans for doing daily activities. Mobile robots is widely developed to reduce human work and easy the job. In this situation, mobile robots can expand work to convey an expanding inclination for mechanical fabricating exercise. Typically, the above-described mobile robots will used in industrials.

However, due to extensive research in mobile robot. There are a lot of application of mobile robots for nowadays. Every situation in which an animal, human or vehicle involves in a useful work today provides a potential application for a mobile robot. Based on reports, by implementing mobile robot in industrial manufactures can improve product

quality, reduce overheads, increase rates of production and so on. Mobile robots types and application will show at the figure below.

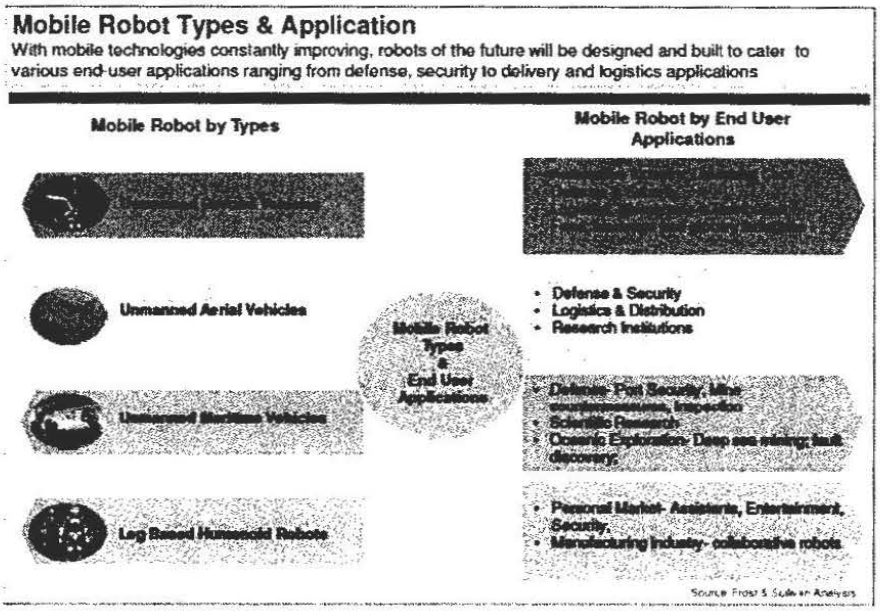

Figure 1.1 Mobile robot types and application.
Source: Frost & Sullivan Analysis, 2014

The widely used type of mobile robots are wheeled mobile robot also can name as WMR. WMR are most popular in mobile robots because WMR is using differential-drive system and it also alternative in simply design and manoeuvrable. Simple explanation for WMR are combination with computational (software) and various physical (hardware) components. In subsystems of WMR are locomotion, sensing, communication, reasoning and control. Each subsystems will apply in WMR.

WMR does not only depend on the tracking system, the control and drive system also necessary. For the control algorithm, it made up with the mathematical model properties in WMR. The mathematical model for WMR can explain in two ways, which are dynamics and kinematic models. Commonly dynamic modelling will be omitted when developing in mathematical models of WMR (Shojaei, Mohammad Shahri, & Tarakameh, 2011). While both modelling are the preferred system accuracy.

Apart from that, navigation mobile robots also famous and widely in the field of robotics. Navigation can be combination of the self –localisation, path planning and map-building competence (Becerra, Courbon, Mezouar, & Sagues, 2010). National Instruments myRIO (NI myRIO) is an embedded hardware device. It can prove

technology and allows to complex engineering systems more quickly, design real and affordably than ever before. NI myRIO can incorporate the interfacing and advantages for programming in LabVIEW (White, Wagner, Blankenau, Wang, & Salazar, 2015).

In this project, the mobile robot is considered as autonomous, if it has a few capabilities. Mobile robot should be able to locate at indoor environment. Lastly, mobile robot should be detect navigate an environment with obstacles while using ultrasonic and Kinect sensor as image capture.

1.2 Problem Statement

Nowadays, service applications using autonomous mobile robot have been considered such as intelligent wheelchair, food delivery and vacuum cleaners mobile robot. For those robots, it must recognize a specific object and it can be required to relocate and approach. The navigation can used in a mobile robot to develop a control system. An optimal navigation system that enables the mobile robot to move in entire area. The choice of vision based object recognition technique for mobile robot have some difficulties such as direction of the mobile robot to move and relocation as required that will involves selecting vision sensor's viewpoint. The most challenging problem is the object detection process because mobile robot need to navigate and place the object in view field. Besides that, the mobile robot also required a vision system that can use in object detection process. The mobile robot can aware to start and target location through the path planning process. While in target position for mobile robot is unknown. Therefore the path should be cover the entire area and maximise the probability for detect the object.

1.3 Project Objective

The objectives of this project are as below:

1. To design a robot with mobility in indoor environment.
2. To accomplish object avoidance using ultrasonic sensor while Kinect sensor as image capturing device
3. To develop LabVIEW simulation for the robot's control.

REFERENCES

This thesis is prepared based on the following references;

Ali, W. G. (2011). A semi-autonomous mobile robot for education and research. *Journal of King Saud University - Engineering Sciences*, *23*(2), 131–138. https://doi.org/10.1016/j.jksues.2011.03.007

Araújo, A., Couceiro, M. S., & Rocha, R. P. (2013). Integrating Arduino - based Educational Mobile Robots in ROS. *13th International Conference on Autonomous Robot Systems*, 9–14. https://doi.org/10.1109/Robotica.2013.6623520

Becerra, H. M., Courbon, J., Mezouar, Y., & Sagues, C. (2010). Wheeled mobile robots navigation from a visual memory using wide field of view cameras. *2010 IEEE/RSJ International Conference on Intelligent Robots and Systems*, 5693–5699. https://doi.org/10.1109/IROS.2010.5650114

CERKALA, J., & JADLOVSKÁ, A. (2015). Nonholonomic Mobile Robot With Differential Chassis Mathematical Modelling and Implementation in Simulink With Friction in Dynamics. *Acta Electrotechnica et Informatica*, *15*(3), 3–8. https://doi.org/10.15546/aeei-2015-0021

Goris, K. (2005). Autonomous mobile robot mechanical design. *Verije University, Brussels*. Retrieved from http://mech.vub.ac.be/multibody/final_works/ThesisKristofGoris.pdf

Hatab, A. A., & Dhaouadi, R. (2013). Dynamic Modelling of Differential-Drive Mobile Robots using Lagrange and Newton-Euler Methodologies: A Unified Framework. *Advances in Robotics & Automation*, *2*(2). https://doi.org/10.4172/2168-9695.1000107

Kim, Y., Kim, S. H., & Kwak, Y. K. (2005). Dynamic analysis of a nonholonomic two-wheeled inverted pendulum robot. *Journal of Intelligent and Robotic Systems: Theory and Applications*, *44*(1), 25–46. https://doi.org/10.1007/s10846-005-9022-4

Klančar, G., Matko, D., & Blai, S. (2011). A control strategy for platoons of differential drive wheeled mobile robot. *Robotics and Autonomous Systems*, *59*(2), 57–64. https://doi.org/10.1016/j.robot.2010.12.002

Lee, S., Oh, S., & Korea, S. (2014). m Onl ad in e b e V y er th si is on fil O e i n s I ly . Bo m Onl ad in e b e V y er th si is on fil O e i n s I ly ., *7*(3), 113–124.

Mak. (2015). Realization of Mini Segway Robot Using NI MyRIO, (February).

Malu, S. K., & Majumdar, J. (2014). Kinematics, Localization and Control of Differential Drive Mobile Robot. *Global Journal of Researches in Engineering*, *14*(1), 1–8.

Meghdari, A. (2004). Dynamics modeling of "cedra" rescue robot on uneven terrains.

Asme 2004 ..., *13*(3), 272–283. https://doi.org/10.1115/IMECE2004-59239

Mester, G. (2006). Motion Control of Wheeled Mobile Robots Modeling of the Wheeled Mobile Robots. *4th Serbian-Hungarian Joint Symposium on Intelligent Systems, SISY*, 119–130.

Rajan, C., Megala, B., Nandhini, A., & Priya, C. R. (2015). A Review : Comparative Analysis of Arduino Micro Controllers in Robotic Car, *9*(2), 371–380.

Ribeiro, F., Moutinho, I., Silva, P., Fraga, C., & Pereira, N. (2004). Three Omni-Directional Wheels Control on a Mobile Robot. *Control 2004*.

Sabto, N. A., & Mutib, K. Al. (2013). Autonomous mobile robot localization based on RSSI measurements using an RFID sensor and neural network BPANN. *Journal of King Saud University - Computer and Information Sciences*, *25*(2), 137–143. https://doi.org/10.1016/j.jksuci.2012.10.001

Shamrao, P. S., & Awale, R. N. (2016). Simulation of nonlinear filter based localization for indoor mobile robot, *4*(5), 183–184. https://doi.org/10.17148/IJIREEICE.2016.4546

Shamsudin, M. A., Mamat, R., & Nawawi, S. W. (2013). Dynamic Modelling and Optimal COntrol Scheme of Wheel Inverted Pendulum for Mobile Robot Application, *3*(6), 1–20.

Sharma, K. (2015). Kinect Sensor based Object Feature Estimation in Depth Images, *8*(12), 237–246.

Shojaei, K., Mohammad Shahri, A., & Tarakameh, A. (2011). Adaptive feedback linearizing control of nonholonomic wheeled mobile robots in presence of parametric and nonparametric uncertainties. *Robotics and Computer-Integrated Manufacturing*, *27*(1), 194–204. https://doi.org/10.1016/j.rcim.2010.07.007

SinghPannu, G., Dawud Ansari, M., & Gupta, P. (2015). Design and Implementation of Autonomous Car using Raspberry Pi. *International Journal of Computer Applications*, *113*(9), 22–29. https://doi.org/10.5120/19854-1789

Song, L., Fei, Y., & Lu, T. (2009). Study on effects of nonholonomic constraints on dynamics of a new developed quadruped leg-wheeled passive mobile robot. *WSEAS Transactions on Systems*, *8*(1), 137–147.

Tölgyessy, M., & Hubinský, P. (2010). The Kinect Sensor in Robotics Education. *International Conference on Robotics in Education*, (November), 143–146.

Ujjainiya, L., & Chakravarthi, M. K. (2015). Raspberry – Pi Based Cost Effective Vehicle Collision Avoidance System Using Image Processing. *ARPN Journal of Engineering and Applied Scieces*, *10*(7), 3001–3005.

Warade, S., Aghav, J., Petitpierre, C., & Udayagiri, S. (2012). Automated Training and Maintenance through KINECT. *International Journal of Computer Science, Engineering and Applications*, *2*(3), 159–172. https://doi.org/10.5121/ijcsea.2012.2315

White, W. N., Wagner, J., Blankenau, B., Wang, Z., & Salazar, V. (2015). Design , Build , and Test of an Autonomous Inverted Pendulum Cart. *The American Control Conference*, 2783–2788.