

## UNIVERSITI MALAYSIA PAHANG

### DECLARATION OF THESIS AND COPYRIGHT

Author's Full Name : EDWIND LIAW YEE KANG

Identification Card No : 920823-13-6147

Title : IMAGE BASED AUTONOMOUS INDOOR  
PARALLEL PARKING ASSIST FOR OMNI-  
DIRECTIONAL VEHICLE (ODV)

Academic Session : 2015/2016

I declare that this thesis is classified as:

☐

**CONFIDENTIAL**

(Contains confidential information under the  
Official Secret Act 1972)

☐

**RESTRICTED**

(Contains restricted information as specified by  
the organization where research was done)\*

☒

**OPEN ACCESS**

I agree that my thesis to be published as online  
open access (Full text)

I acknowledge that Universiti Malaysia Pahang reserve the right as follows:

1. The Thesis is the Property of University Malaysia Pahang.
2. The Library of University Malaysia Pahang has the right to make copies for the purpose of research only.
3. The Library has the right to make copies of the thesis for academic exchange.

Certified by:

\_\_\_\_\_  
(Author's Signature)

\_\_\_\_\_  
(Supervisor's Signature)

EDWIND LIAW YEE KANG

(Author's Name)

ASSOC PROF DR ABDUL AZIZ BIN JAAFAR

(Supervisor's Name)

Date: 10<sup>th</sup> JUNE 2016

Date: 10<sup>th</sup> JUNE 2016

# IMAGE BASED AUTONOMOUS INDOOR PARALLEL PARKING ASSIST ON OMNI- DIRECTIONAL VEHICLE (ODV)

EDWIND LIAW YEE KANG

Report submitted in partial fulfillment of the requirements  
for the award of the degree of  
Bachelor of Engineering (HONs) in Mechatronics Engineering

Faculty of Manufacturing Engineering  
UNIVERSITI MALAYSIA PAHANG

June 2016

### **SUPERVISOR'S DECLARATION**

I hereby declare that I 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 Mechatronics Engineering.

Signature : .....

Name of supervisor : ASSOC. PROF. DR. ABDUL AZIZ BIN JAAFAR

Position : ASSOC. PROF. OF UNIVERSITY MALAYSIA PAHANG

Date : 10<sup>th</sup> JUNE 2016

Signature : .....

Name of co-supervisor : MR. ISMAIL BIN MOHD KHAIRUDDIN

Position : LECTURER OF UNIVERSITY MALAYSIA PAHANG

Date : 10<sup>th</sup> JUNE 2016

### **STUDENT'S DECLARATION**

I hereby declare that the work in this report is my own except for quotation and summaries which have been duly acknowledged. The report has not been accepted for any degree and is not concurrently submitted for award of other degree.

Signature : .....

Name : EDWIND LIAW YEE KANG

ID Number : FB12058

Date : 10<sup>th</sup> JUNE 2016

## TABLE OF CONTENTS

	<b>Page</b>
<b>SUPERVISOR’S DECLARATION</b>	iii
<b>STUDENT’S DECLARATION</b>	iv
<b>ACKNOWLEDGEMENTS</b>	v
<b>ABSTRACT</b>	vi
<b>ABSTRAK</b>	vii
<b>TABLE OF CONTENTS</b>	viii
<b>LIST OF TABLES</b>	xii
<b>LIST OF FIGURES</b>	xiii
<b>LIST OF SYMBOLS</b>	xxi
<b>LIST OF ABBREVIATIONS</b>	xxii

### **CHAPTER 1 INTRODUCTION**

1.1	Introduction	1
1.2	Problem Statement	4
1.3	Project Objectives	4
1.4	Project Scope	5

### **CHAPTER 2 LITERATURE REVIEW**

2.1	Introduction	6
2.2	Ground Vehicle	6

2.3	Omni-Directional vehicle (ODV)	9
2.3.1	History and Development	10
2.3.2	Omnidirectional Motion	11
2.3.3	Roller Wheels	12
2.3.4	Mecanum Wheels	13
2.3.5	Mecanum Drive VS Holonomic Drive	18
2.4	Autonomous Vehicle Navigation	19
2.5	Sensor Theory and Vision Based Sensors	19
2.6	Image Based Object Tracking	21
2.7	Image Processing	25
2.7.1	Image Processing Techniques	25
2.7.2	Image Segmentation	26
2.7.3	Contour	38
2.8	Parking Guidance and Information	42

## **CHAPTER 3 METHODOLOGY**

3.1	Introduction	46
3.2	Project Flow Chart	47
3.3	Stage of Literature Review	49
3.4	Proposed Solution	50
3.5	Imaging System	52
3.6	Image Processing Algorithm	56
3.6.1	Development Tools	56
3.6.2	Image Processing Algorithm	59
3.7	Omni-Directional Vehicle	75
3.7.1	Electronics Components	75
3.7.1.1	Arduino Mega 2560	75
3.7.1.2	MD-10 Motor Driver Shield	76
3.7.1.3	Faulhaber Motor 23421012cr	77

3.7.1.4	Ultrasonic Sensors	78
3.7.1.5	Push Button	79
3.7.1.6	Motor Encoder	80
3.7.1.7	Lithium Polymer Battery	81
3.7.2	Vehicle's Controller Programming	83
3.8	Hardware Design	100
3.9	Experimental Set Up	102
3.10	Performance Analysis	104

## **CHAPTER 4 RESULTS AND DISCUSSION**

4.1	Introduction	111
4.2	Imaging System	111
4.2.1	Image Processing Algorithm	111
4.2.2	Imaging System Performance Analysis	118
4.3	Omni-Directional Vehicle (ODV)	122
4.3.1	Motor Speed	122
4.3.2	Parking Performance	129
4.3.3	Motion Path of the ODV	140

## **CHAPTER 5 CONCLUSION AND RECOMMENDATION**

5.1	Introduction	149
5.2	Conclusion	149
5.3	Limitation	150
5.4	Recommendation	150

<b>REFERENCES</b>	151
-------------------	-----

<b>APPENDICES</b>	155
-------------------	-----

A	Final Year Project 1 Gantt Chart	155
B	Final Year Project 2 Gantt Chart	156
C	Image Processing Algorithm	157
D	Arduino Program Code	167



**LIST OF TABLES**

<b>Table No.</b>	<b>Title</b>	<b>Page</b>
2.1	Types of motion for ground vehicles	8
2.2	Comparative study between Holonomic and Mecanum drive	18
2.3	Sensor types	20
3.1	Lux value for different environment	105
4.1	Raw data of the imaging tracking experiment	119
4.2	Summarized result of the imaging tracking experiment	121
4.3	Summary of 6 conditions of experiment	129
4.4	Average time of completing parallel parking	139

## LIST OF FIGURES

<b>Figure No.</b>	<b>Title</b>	<b>Page</b>
1.1	Self-driving vehicle by Google	2
1.2	Omnidirectional forklift	3
2.1	An omnidirectional ground vehicle	9
2.2	Drawing of the first omnidirectional wheel	11
2.3	Roller Wheel Design	13
2.4	Omni-Directional vehicle (ODV) with roller wheels	13
2.5	Mecanum Wheels Design	14
2.6	Omnidirectional vehicle with mecanum wheels	14
2.7	Mecanum wheels rotating	15
2.8	Top view of rotating mecanum wheels	16
2.9	Motion by Mecanum wheeled vehicles	17
2.10	Motion of omni (roller) wheeled vehicles	17
2.11	General architecture of Foresti's surveillance system	22
2.12	Result of Foresti's surveillance system	23
2.13	General architecture of the video picture based object tracking approach	24
2.14	Process of simple thresholding	28
2.15	Red color object being thresholded and segmented	32

2.16	No object being detected	32
2.17	System modules	33
2.18	Original image captured by camera (Image acquisition step)	34
2.19	Segmented image (Binary form)	35
2.20	Binary image after being enhanced	36
2.21	Results of image segmentation	37
2.22	Steps in sing detection and extraction stage	39
2.23	Result of the gesture recognition by using contour	41
2.24	Steps in sing detection and extraction stage	42
2.25	Result of the gesture recognition by using contour	43
3.1	Project Flow Chart part 1	47
3.2	Project Flow Chart part 2	48
3.3	System block diagram	51
3.4	Working principle of ordinary omnidirectional camera	53
3.5	Specially designed omnidirectional camera for this system	53
3.6	Set up of the omnidirectional camera	54
3.7	Set up of the omnidirectional camera	55
3.8	View of the omnidirectional camera	55
3.9	Logo of Visual Studio	56

3.10	Logo of OpenCV	58
3.11	Image processing algorithm flow chart part 1	59
3.12	Image processing algorithm flow chart part 2	60
3.13	Image processing algorithm part 1	61
3.14	Image processing algorithm part 2	62
3.15	Image frame and pixel	63
3.16	Image processing algorithm part 3	64
3.17	Original image	64
3.18	Thresholded image	65
3.19	HSV value for the green color	65
3.20	Image processing algorithm part 4	66
3.21	Image processing algorithm part 5 (Function of morphOps)	66
3.22	Image processing algorithm part 6 (Function of object tracking)	67
3.23	Image processing algorithm part 6 (Function of object tracking)	68
3.24	Calculation of centroid	69
3.25	Object tracking indication	69
3.26	Function of drawing marking on detected object	70
3.27	Image processing algorithm part 7 (Object tracking for right ROI)	71
3.28	Function of drawing indication line on detected object on right ROI	72

3.29	Main functions of image processing algorithm part 1	73
3.30	Main functions of image processing algorithm part 2	74
3.31	Arduino Mega 2560	76
3.32	MD-10 Motor Driver Shield	77
3.33	Faulhaber Motor 2342l012cr	78
3.34	Ultrasonic Sensor	79
3.35	Push Button	80
3.36	Motor encoder HEDM-5500	81
3.37	LiPo battery	82
3.38	Flow chart of Omni-Directional Vehicle's controller (1st Part)	84
3.39	Function of ultrasonic()	85
3.40	Flow chart of Omni-Directional Vehicle's controller (2nd Part)	87
3.41	Code 'A'	88
3.42	First part of the code in speed_adjustment() function	90
3.43	Encoder() and Encoder2() function	92
3.44	Encoder3() and Encoder4() function	93
3.45	Functions of reading encoder position for 1 <sup>st</sup> and 2 <sup>nd</sup> encoder	94
3.46	Functions of reading encoder position for 3rd and 4th encoder	95
3.47	attachInterrupt for 4 functions	95

3.48	Code 'B'	97
3.49	Flow chart of Omni-Directional Vehicle's controller (4th Part)	99
3.50	System block diagram	101
3.51	Hardware set up	102
3.52	Front view of the virtual indoor car park	103
3.53	Working principle of omnidirectional camera	103
3.54	Experimental set up	104
3.55	1 <sup>st</sup> Experiment	106
3.56	2 <sup>nd</sup> Experiment	107
3.57	3 <sup>rd</sup> Experiment	108
3.58	4 <sup>th</sup> Experiment	109
3.59	5 <sup>th</sup> Experiment	109
3.60	6 <sup>th</sup> Experiment	110
4.1	Image feed in 1st condition (Lighted up indicator on right side)	112
4.2	Location and pixel area of detected object in 1st condition (Lighted up indicator on right side)	113
4.3	Image feed in 2nd condition (Lighted up indicator on left side)	114
4.4	Location and pixel area of detected object in 2nd condition (Lighted up indicator on left side)	115
4.5	Image feed in 3rd condition (Lighted up indicator on both sides)	116

4.6	Location and pixel area of detected object in 3rd condition (Lighted up indicator on both sides)	117
4.7	Imaging tracking at lux of 379	118
4.8	Imaging tracking at lux of 6	119
4.9	Motor 1 Acceleration without speed adjustment function	123
4.10	Motor 2 Acceleration without speed adjustment function	123
4.11	Motor 3 Acceleration without speed adjustment function	124
4.12	Motor 4 Acceleration without speed adjustment function	124
4.13	Comparison of acceleration between 4 motors without speed adjustment function	125
4.14	Motor 1 Acceleration with speed adjustment function	126
4.15	Motor 2 Acceleration with speed adjustment function	126
4.16	Motor 3 Acceleration with speed adjustment function	127
4.17	Motor 4 Acceleration with speed adjustment function	127
4.18	Comparison of acceleration between 4 motors with speed adjustment function	128
4.19	Set up of 1 <sup>st</sup> experiment	130
4.20	Completion of parallel parking for 1 <sup>st</sup> experiment	131
4.21	Parking alignment of the ODV in 1 <sup>st</sup> experiment	131
4.22	Set up of 2 <sup>nd</sup> experiment	132
4.23	Completion of parallel parking for 2 <sup>nd</sup> experiment	133

4.24	Parking alignment of the ODV in 2 <sup>nd</sup> experiment	133
4.25	Set up of 3 <sup>rd</sup> experiment	134
4.26	Completion of parallel parking for 3 <sup>rd</sup> experiment	135
4.27	Parking alignment of the ODV in 3 <sup>rd</sup> experiment	135
4.28	Set up of 4 <sup>th</sup> experiment	136
4.29	Completion of parallel parking for 4 <sup>th</sup> experiment	137
4.30	Parking alignment of the ODV in 4 <sup>th</sup> experiment	137
4.31	Set up of 5 <sup>th</sup> experiment	138
4.32	Set up of 6 <sup>th</sup> experiment	138
4.33	Initial position of the ODV	140
4.34	Movement of ODV to left	141
4.35	Movement of ODV to right	142
4.36	Alignment of the ODV in right parking space (with speed control function)	143
4.37	Alignment of the ODV in right parking space (with speed control function)	143
4.38	Alignment of the ODV in left parking space (with speed control function)	144
4.39	Alignment of the ODV in left parking space (with speed control function)	144



4.40	Alignment of the ODV in right parking space (without speed control function)	145
4.41	Alignment of the ODV in right parking space (without speed control function)	146
4.42	Alignment of the ODV in left parking space (without speed control function)	147
4.43	Alignment of the ODV in left parking space (without speed control function)	148

**LIST OF SYMBOLS**

$x'$	Center of mass in coordinate X in contour
$y'$	Center of mass in coordinate Y in contour

## **LIST OF ABBREVIATIONS**

CATIA    Computer Aided Three-dimensional Interactive Application

ODV      Omni-Directional Vehicle

OpenCV   Open Source Computer Vision

# IMAGE BASED AUTONOMOUS INDOOR PARALLEL PARKING ASSIST ON OMNI- DIRECTIONAL VEHICLE (ODV)

EDWIND LIAW YEE KANG

Report submitted in partial fulfillment of the requirements  
for the award of the degree of  
Bachelor of Engineering (HONs) in Mechatronics Engineering

Faculty of Manufacturing Engineering  
UNIVERSITI MALAYSIA PAHANG

June 2016

## **ABSTRACT**

Nowadays, Omni-Directional Vehicle (ODV) has been widely used in many fields to perform autonomous missions. Equipped with sensors and pre-programmed navigation systems, ODV can be designed to replace humans in performing dangerous tasks in various fields such as planet exploration and industrial applications. In this research, the implementation of image processing techniques on vehicle's control has been proposed to develop autonomous indoor parallel parking assist on ODV. The image processing algorithm is first developed using Visual Studio C++ and OpenCV. The electrical circuit of the ODV has been designed and installed. Then, the developed image processing algorithm is integrated with the microcontroller of the ODV, Arduino Mega 2560. After that, an experimental environment has been constructed and set-up to test and analyze the performance of the developed system. As a result, the proposed and developed system is able to work in indoor lighting range.

## **ABSTRAK**

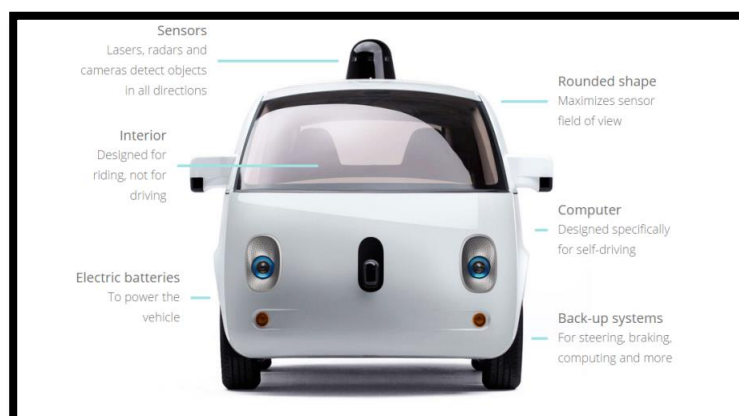
Pada zaman kini, Kendaraan Omni-Directional (ODV) telah luas digunakan dalam pelbagai bidang untuk melaksanakan tugas-tugas berautonomi. Dilengkapi dengan alat pengesan dan sistem navigasi yang telah diprogramkan, ODV boleh direkakan untuk menggantikan tenaga manusia dalam melaksanakan tugas berbahaya dalam pelbagai bidang seperti penerokaan planet dan aplikasi perindustrian. Dalam pengajian ini, pelaksanaan teknik pemprosesan imej dalam pengawalan kenderaan telah digunakan untuk mengembangkan parkir paralel autonomi pada ODV. Algoritma pemprosesan imej pertama kali dikembangkan dengan menggunakan Visual Studio C++ dan Open CV. litar elektrik ODV telah direkakan dan dipasangkan. Kemudian, algoritma pemprosesan imej yang telah dikembangkan telah diintegrasikan dengan pengawal mikro ODV, Arduino Mega 2560. Selepas itu, suatu alam sekitar yang bersifat uji kaji akan dibina dan distrukturkan untuk menguji dan menganalisis prestasi sistem.

## **CHAPTER 1**

### **INTRODUCTION**

#### **1.1 INTRODUCTION**

Over the years of continuous revolution in the automotive vehicles, autonomous features have been the key in advancing the automotive technology. According to NHTSA of US, autonomous or self-driving vehicles are defined as the vehicle that can operate without the needs of direct input or manipulation from the driver [1]. Lately, many self-driving vehicles have been developed for industries and factories. For example, Google has been working on developing autonomous or self-driving vehicle. The vehicle will take the passengers to the place that they want to be with just a press of a button. Figure 1.1 below illustrates how the self-driving vehicle developed by Google.



**Figure 1.1:** Self-driving vehicle by Google

Source: Google 2015

Moreover, a Canadian company which is in expertise maker of field and service robots, Clearpath Robotics, has successfully developed new self-driving car named OTTO. The moving platform is specially designed for carrying load in industrial environments like factories and warehouses [2]. Hence, it is believed that the revolution that will be implemented on the vehicle is the autonomous feature.

Other than autonomous features, another revolution that has been made over automotive vehicle is the technology of omnidirectional driving. Compared to conventional automotive vehicles, Omni-Directional Vehicles can change the travel direction without steering the rear and front wheels. Omnidirectional driving has featured the vehicles relatively lower turning radius in comparison to conventional vehicles. This makes the Omni-Directional vehicle (ODV) ultimately helpful in tight environment especially in floor of factory or any other manufacturing environments [2]. This can be supported by the fact that omnidirectional driving has also been implemented on forklift.



Figure 1.2 below shows the figure of omnidirectional forklift. Thereby, it is noticeable that the popularity of omnidirectional driving is increasing especially in the field of industry.



**Figure 1.2:** Omnidirectional forklift

Source: Oemoffhighway 2015

In this research, an image based automatic indoor parallel parking assist system is to be developed for the Omni-Directional vehicle (ODV). As a part of autonomous features, automatic parking is necessary to be implemented onto the vehicles. This is because autonomous or self-driving vehicle will definitely need to be able to perform the automatic parking. The vehicle will need to determine the availability of the parking lot and perform the parking. In general, the car park can be mainly categorized into outdoor and indoor car parks. There are also various types of parking methods that a vehicle can perform. For example, there are angular parking, perpendicular parking, parallel parking. In this paper, the discussion will only focus on how the Omni-Directional vehicle (ODV)

## REFERENCES

This thesis is prepared based on the following references:

- [1] Adăscăliței, F., & Doroftei, I. (2011). Practical Applications for Mobile Robots based on Mecanum Wheels -. Proceedings of International Conference On Innovations, Recent Trends And Challenges In Mechatronics, Mechanical Engineering And New High-Tech Products Development – MECAHITECH’11, 3(Figure 1), 112–123.
  
- [2] Bräunl, T. 2015. Omni-directional Vehicles. (online)  
  
<http://robotics.ee.uwa.edu.au/omni/> (16 October 2015)
  
- [3] Damoto, R., Cheng, W. and Hirose, S. 2001. Holonomic Omni-Directional vehicle (ODV) with New Omni-Wheel Mechanism. Proceedings of the 2001 IEEE International Conference on Robotics & Automation, pp. 773-778.
  
- [4] Department of Transport UK. Traffic Advisory Leaflet. (2003). (Online)  
  
<http://web.archive.org/web/20070206041939/http://www.dft.gov.uk/pgr/roads/tpm/tal/its/parkingguidanceandinformation> (2 April 2016)
  
- [5] Diegel, O., Badve, A., Bright, G., Potgieter, J., & Tlale, S. (2002). Improved Mecanum Wheel Design for Omni-directional Robots. Shinji Kamiuchi and Shoichi Maeyama, “A Novel Human Interface of an Omni-Directional Wheelchair”, Int. Workshop on Robot and Human Interactive Communication, 2004, Pp. 101-106., (November), 27–29.

- [6] Doroftei, I., Stirbu, B., “Design, Modeling and Control of an Omni-directional Mobile Robot”, Solid State Phenomena Vols. 166-167, 2010, pp 173-178, Trans Tech Publications, Switzerland.doi:10.4028/www.scientific.net/SSP.166-167.173.
  
- [7] Halvorson, B. (2015). BMW Debuts New Parking Assistant In 2011 (Online).  
  
[http://www.thecarconnection.com/news/1041977\\_bmw-debuts-new-parking-assistant-in-2011-5-series](http://www.thecarconnection.com/news/1041977_bmw-debuts-new-parking-assistant-in-2011-5-series)
  
- [8] Ishigami, G., Overholt, J., & Iagnemma, K. (2012). Multi-material anisotropic friction wheels for omnidirectional ground vehicles. *Journal of Robotics and Mechatronics*, 24(1), 261–267.
  
- [9] Kurukshetra, N. I. T. (2015). *Image Processing and Object Detection*, 1(9), 396–399.
  
- [10] Lorsakul, A., and Suthakorn, J. 2007. Traffic Sign Recognition for Intelligent Vehicle/Driver Assistance System Using Neural Network on OpenCV. The 4th International Conference on Ubiquitous Robots and Ambient Intelligence (URAI 2007)
  
- [11] Morimoto, T., Kiriya, O., Harada, Y., Adachi, H., Koide, T., Hans, J., & Segmentation, A. I. (2005). Object Tracking in Video Pictures based on Image Segmentation and Pattern Matching, 1–4.
  
- [12] National Highway Traffic Safety Administration (NHTSA). 2013. U.S. Department of Transportation Releases Policy on Automated Vehicle Development (online).

[http://www.nhtsa.gov/About NHTSA/Press Releases/U.S. Department of Transportation Releases Policyon Automated Vehicle Development](http://www.nhtsa.gov/About+NHTSA/Press+Releases/U.S.+Department+of+Transportation+Releases+Policyon+Automated+Vehicle+Development) (17 October 2015)

- [13] Nicholas, G. 2015. Self-driving cars will cruise the factory floor before they're big on the open road (online)

<http://www.zdnet.com/article/selfdrivingcarsforthefactoryfloor/>(17 October 2015)

- [14] Nick Efford. Digital Image Processing: A Practical Introduction Using Java™. Pearson Education, 2000.

- [15] Rafael C. Gonzalez; Richard E. Woods (2008). Digital Image Processing. Prentice Hall. pp. 1–3. ISBN 978-0-13-168728-8.

- [16] RobotShop Blog. 2012. What Types of Mobile Robots are There (online)

<http://www.robotshop.com/blog/en/what-types-of-mobile-robots-are-there-3652>

- [17] The University of Auckland. 2012. Image Segmentation (online).

<https://www.cs.auckland.ac.nz/courses/compsci773s1c/lectures/ImageProcessing-html/topic3.htm> (26 April 2016).

- [18] Wiesenfelder, B. J., & Ls, L. (2015). The Lexus LS460 : It Really Does Park Itself, 1–10.

- [19] Yang, M. H., and Ahuja, N. (1999). Detecting human faces in color images. *Image and Vision Computing*, 18(1), 63–75. [http://doi.org/10.1016/S0262-8856\(99\)00006-2](http://doi.org/10.1016/S0262-8856(99)00006-2)
  
- [20] Yusnita, R., Fariza N., and Norazwinawati B. 2012. Intelligent Parking Space Detection System Based on Image Processing. *International Journal of Innovation, Management and Technology*, Vol. 3, No. 3