ESTIMATION OF CONFIGURATION WORKSPACE FOR A ROBOT-CONTROLLED VISION INSPECTION SYSTEM

NUR SUFIAH AKMALA BINTI RAMDAN
B050910070

UNIVERSITI TEKNIKAL MALAYSIA MELAKA
2013

B050910070 BACHELOR OF MANUFACTURING ENGINEERING (ROBOTICS & AUTOMATION) (HONS.) 2013 UTeM

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

ESTIMATION OF CONFIGURATION WORKSPACE FOR A ROBOT-CONTROLLED VISION INSPECTION SYSTEM

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering (Robotic and Automation) (Hons.)

by

NUR SUFIAH AKMALA BINTI RAMDAN
B050910070
900319-06-5126

FACULTY OF MANUFACTURING ENGINEERING

2013

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: **NUR SUFIAH AKMALA BINTI RAMDAN**

SESI PENGAJIAN: 2012/2013 Semester 2

Saya **NUR SUFIAH AKMALA BINTI RAMDAN**

mengaku membenarkan Laporan PSM ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Laporan PSM adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan laporan PSM ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (√)

☐ SULIT (Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysiasebagaimana yang termaktub dalam AKTA RAHSIA RASMI 1972)

☐ TERHAD (Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)

☐ TIDAK TERHAD

Disahkan oleh:

________________________ ________________________

Alamat Tetap:

NO. 14, Jalan Kurnia 1,

Taman Kurnia Jaya, 25150

Kuantan, Pahang

Cop Rasmi:

Tarikh: ________________________

Tarikh: ________________________

** Jika Laporan PSM ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan PSM ini perlu dikelaskan sebagai SULIT atau TERHAD.

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Robotics and Automation) (Hons.). The member of the supervisory is as follow:

………………………………

(Project Supervisor)

ABSTRAK

Konfigurasi ruang kerja adalah mengenai pergerakan robot. Ia adalah berkaitan dengan algoritma set pergerakan lengan robot. Algoritma harus direka untuk memenuhi keperluan untuk menggerakkan robot dengan gerakan yang diingini. Pergerakan lengan robot perlu direka bentuk untuk melakukan pemeriksaan berdasarkan pemprosesan imej digital oleh kamera. Projek ini akan disimulasi pada awalnya dengan menggunakan perisian Workspace, untuk memastikan bahawa ia mampu melakukan pergerakan yang diingini. Kemudian, hasilnya akan diterjemahkan ke dalam persekitaran sebenar dengan pengaturcaraan robot sebenar. Hasilnya ditunjukkan sebagai algoritma yang lengkap untuk menggerakkan robot dan bagaimana konfigurasi ruang kerja yang dilakukan untuk reka bentuk sistem ini. Keputusan telah diperolehi melalui pergerakan robot yang telah dibangunkan. Oleh itu anggaran yang terbaik daripada ruang kerja konfigurasi dapat diperolehi . Ini termasuk pergerakan, halaju dan pecutan sendi robot.

Kata kunci: Konfigurasi ruang kerja, robot serial, pengimbas pemeriksaan.

ABSTRACT

Configuration workspace is related to the algorithm sets and movement of the robot. The algorithm must be designed to fulfill the requirement for moving the robot with the desired motion. For this robot-controlled vision inspection system, the movement of the robot arm must be design to do the inspection based on the image processing. The project will be first simulated using the Workspace software, to make sure that the robot can achieve the desired movement and angle. After that, the result will be translated into real environment, which is the programming of the real robot and the automatic inspection. The result is shown as a complete algorithm to move the robot and how the workspace configuration is done to design this “Robotic Controlled Vision Inspection System”. Therefore the best estimation of configuration workspace can be obtained from the results, including the position, velocity and acceleration of the robot’s joints.

Key words: Configuration space, serial robot, vision inspection.

DEDICATION

To my father Ramdan Razali , my mother Wan Maseri and all my siblings, I love you. Special to all Palestinian people, all Muslims and all good people in the world who are living in war, poverty and torture, I finished my Final Year Project is because of you. I really hope that I can help you with all knowledge that I gain one day.

ACKNOWLEDGEMENT

I would like to thank to my Supervisor Dr. Ahmad Yusairi Bin Bani Hashim, who has lead me along the journey to complete this project and teach me a lot of techniques to do with it. I also want to give a very special thanks to PHN Industry Sdn. Bhd. upon their willingness of giving me the opportunity to do my Industrial Training there, and be cooperating with me in completing this final year project. Hopefully this project will bring success to me and to PHN Industry Sdn. Bhd.

TABLE OF CONTENT

Abstrak	i
Abstract	ii
Dedication	iii
Acknowledgement	iv
Table of content	v
List of tables	viii
List of figures	x
List of abbreviation, symbols and nomenclature	xvi
CHAPTER 1: INTRODUCTION	**1**
1.1 Background	1
1.1.1 The industrial vision inspection system evolution	2
1.2 Problem statement	4
1.3 Objective	4
1.4 Scopes	5
1.5 Expected outcome	5
1.6 Project planning	7
CHAPTER 2: LITERATURE REVIEW	**8**
2.1 Types of industrial robot	8
2.1.1 Robot manipulator	11
2.1.2 End effector	11
2.2 Serial robots in inspection process	12
2.3 Path and trajectory planning	13
2.3.1 The configuration workspace	13
2.3.2 Method of configuration space	14
2.3.3 Method in trajectory planning	15

CHAPTER 3: METHODOLOGY **18**
3.1 Identification of the method in path and trajectory planning 19
3.1.1 Experiment 1: Methods for path and trajectories planning 19
3.2 Design of the programming structure 23
3.2.1 Experiment 2: Robot programming 23
3.3 Development of the programs 26
3.3.1 Experiment 3: Program implementations 26
3.4 Assessment of the robot's paths and trajectories 32
3.4.1 Experiment 4: Tests the robot in motion 32

CHAPTER 4: RESULT AND ANALYSIS **34**
4.1 Identification of the method in path and trajectory planning
4.1.1 Experiment 1: Method for path and trajectory planning 34
4.1.1.1 Results 34
4.1.1.2 Discussions 34
4.2 Design of the programming structure
4.2.1 Experiment 2: Robot programming by Workspace 5 software 39
4.2.1.1 Results, analysis and discussions 39
4.2.1.1.1 Drawing of all parts by Workspace 5 39
4.2.1.1.2 The simulation set-up 54
4.2.1.1.3 The simulation movement 57
4.2.1.1.4 The simulation analysis 65
4.2.1.1.5 Discussions 103
4.3 Development of the program 104
4.3.1 Experiment 3: Program implementations 104
4.3.1.1 Results, analysis and discussions 104
4.3.1.1.1 The detail experimental set-up 104
4.3.1.1.2 The simulation movement 109
4.3.1.1.3 The simulation analysis 118
4.3.1.1.4 Discussions 156

4.4 Assessment of the robot’s paths and trajectories 157
4.4.1 Experiment 4: Test the robot in motion 157
4.4.1.1 Results 157
4.4.1.2 Discussions 158

CHAPTER 5: CONCLUSION AND FUTURE WORK 159

REFERENCES 160

APPENDICES 162
Appendix A The dimension and work envelope of Smart NS robot 162

LIST OF TABLES

3.1	The estimated trajectory	21
3.2	The results for planning the tool path	29
3.3	The trajectories data	30
3.4	The table for data of robot movement	33
4.1	The estimated path and trajectory	37
4.2	Data for joint 1 with the speed of 20 %	66
4.3	Data for joint 2 with the speed of 20 %	69
4.4	Data for joint 3 with the speed of 20 %	72
4.5	Data for joint 4 with the speed of 20 %	75
4.6	Data for joint 5 with the speed of 20 %	78
4.7	Data for joint 6 with the speed of 20 %	81
4.8	Data for joint 1 with the speed of 30 %	85
4.9	Data for joint 2 with the speed of 30 %	88
4.10	Data for joint 3 with the speed of 30 %.	91
4.11	Data for joint 4 with the speed of 30 %	94
4.12	Data for joint 5 with the speed of 30 %	97
4.13	Data for joint 6 with the speed of 30 %	100
4.14	Data for joint 1 with 20 % speed	119
4.15	Data for joint 2 with 20 % speed	122
4.16	Data for joint 3 with 20 % speed	125
4.17	Data for joint 4 with 20 % speed	128
4.18	Data for joint 5 with 20 % speed	131
4.19	Data for joint 6 with 20 % speed	134
4.20	Data for joint 1 with 30 % speed	138
4.21	Data for joint 2 with 30 % speed	141
4.22	Data for joint 3 with 30 % speed	144
4.23	Data for joint 4 with 30 % speed	147
4.24	Data for joint 5 with 30 % speed	150

4.25 Data for joint 6 with 30 % speed 153

LIST OF FIGURES

1.1	The machine vision inspection system evolution	2
1.2	A typical industrial vision sytem	3
1.3	A robot-controlled vision inspection sytem	3
1.4	K-chart of the project	6
2.1	Comou 6-axis serial robot, model Smart5 NJ	9
2.2	ABB parallel robot, FlexPicker, model IRB 340	9
2.3	Mobile robot build by Neurotechnology	10
2.4	Smart M1 Inline complete work envelope	10
2.5	The classification of inspection features and inspection	12
	elements	15
2.6	Example of workspace, configuration space and reference	
	point	
3.1	The flow of the project realization process	18
3.2	The car’s door that will be the object to be tested	20
3.3	Image of Workspace simulation taken from the Workspace	23
	software	
3.4	The model of the robot	27
3.5	The experimental set-up	28
4.1	The actual car’s door	34
4.2	The car’s door sketching	35
4.3	The car’s door sketching with robot	35
4.4	The planned path for the inspection process	36
4.5	Comau Smart M1 Inline	39
4.6	Comau Smart M1 Inline side view	40
4.7	Comau Smart M1 Inline wireframe	40
4.8	Comau Smart M1 Inline top view with dimension	41

4.9	Robot's envelope for joint 1 and joint 2	42
4.10	Robot's envelope for joint 3 and joint 4	42
4.11	Robot's envelope for joint 5 and joint 6	43
4.12	Robot's envelope for all joints	43
4.13	Gripper	44
4.14	Gripper top view with dimension	44
4.15	Gripper wireframe view	45
4.16	Gripper with camera	45
4.17	Gripper with camera top view	46
4.18	Gripper with camera through wireframe view and dimension	46
4.19	Car's door	47
4.20	Car's door with dimension	47
4.21	Car's door with wireframe view	48
4.22	The screws at the right side of the door	49
4.23	The screws at the left side of the door	49
4.24	The door holder	50
4.25	The door holder with dimension	50
4.26	The door holder with wireframe view	51
4.27	The door within inspection point	52
4.28	The simulation set-up for robot and car's door	54
4.29	The simulation set-up for robot and car's door (side view)	55
4.30	The simulation set-up for robot and car's door (top view)	55
4.31	Robot's envelope with the door	56
4.32(a)	Home position	57
4.32(b)	Initial point	57
4.32(c)	Safety point 1	58
4.32(d)	Point 1	58
4.32(e)	Safety point 2	59
4.32(f)	Point 2	59
4.32(g)	Safety point 3	60
4.32(h)	Point 3	60
4.32(i)	Point 4	61

4.32(j)	Safety point 4	61
4.32(k)	Safety point 5	62
4.32(l)	Point 5	62
4.32(m)	End point	63
4.32(n)	Home position with complete path	63
4.33	The Microsoft Excel file	65
4.34(a)	Graph of joint value versus time for joint 1 with 20 % speed	67
4.34(b)	Graph of velocity versus time for joint 1 with 20 % speed	67
4.34(c)	Graph of acceleration versus time for joint 1 with 20 % speed	68
4.35(a)	Graph of joint value versus time for joint 2 with 20 % speed	70
4.35(b)	Graph of velocity versus time for joint 2 with 20 % speed	70
4.35(c)	Graph of acceleration versus time for joint 2 with 20 % speed	71
4.36(a)	Graph of joint value versus time for joint 3 with 20 % speed	73
4.36(b)	Graph of velocity versus time for joint 3 with 20 % speed	73
4.36(c)	Graph of acceleration versus time for joint 3 with 20 % speed	74
4.37(a)	Graph of joint value versus time for joint 4 with 20 % speed	76
4.37(b)	Graph of velocity versus time for joint 4 with 20 % speed	76
4.37(c)	Graph of acceleration versus time for joint 4 with 20 % speed	77
4.38(a)	Graph of joint value versus time for joint 5 with 20 % speed	79
4.38(b)	Graph of velocity versus time for joint 5 with 20 % speed	79
4.38(c)	Graph of acceleration versus time for joint 5 with 20 % speed	80
4.39(a)	Graph of joint value versus time for joint 6 with 20 % speed	82
4.39(b)	Graph of velocity versus time for joint 6 with 20 % speed	82
4.39(c)	Graph of acceleration versus time for joint 6 with 20 % speed	83
4.40	Graph of all joint position in Workspace with 20 % speed	83
4.41(a)	Graph of joint value versus time for joint 1 with 30 % speed	86
4.41(b)	Graph of velocity versus time for joint 1 with 30 % speed	86
4.41(c)	Graph of acceleration versus time for joint 1 with 30 % speed	87
4.42(a)	Graph of joint value versus time for joint 2 with 30 % speed	89
4.42(b)	Graph of velocity versus time for joint 2 with 30 % speed	89
4.42(c)	Graph of acceleration versus time for joint 2 with 30 % speed	90
4.43(a)	Graph of joint value versus time for joint 3 with 30 % speed	92

4.43(b)	Graph of velocity versus time for joint 3 with 30 % speed	92
4.43(c)	Graph of acceleration versus time for joint 3 with 30 % speed	93
4.44(a)	Graph of joint value versus time for joint 4 with 30 % speed	95
4.44(b)	Graph of velocity versus time for joint 4 with 30 % speed	95
4.44(c)	Graph of acceleration versus time for joint 4 with 30 % speed	96
4.45(a)	Graph of joint value versus time for joint 5 with 30 % speed	98
4.45(b)	Graph of velocity versus time for joint 5 with 30 % speed	98
4.45(c)	Graph of acceleration versus time for joint 5 with 30 % speed	99
4.46(a)	Graph of joint value versus time for joint 6 with 30 % speed	101
4.46(b)	Graph of velocity versus time for joint 6 with 30 % speed	101
4.46(c)	Graph of acceleration versus time for joint 6 with 30 % speed	102
4.47	Graph of all joint position in Workspace with 30 % speed	102
4.48	Experimental set-up	104
4.49	The door with 15cm marker	105
4.50	The door with marker	105
4.51	The camera	106
4.52	The camera front view	106
4.53	Camera position	107
4.54	Student teaching the robot	107
4.55(a)	Home position	109
4.55(b)	Initial position	109
4.55(c)	Safety Point 1	110
4.55(d)	Safety Point 2	110
4.55(e)	Point 1	111
4.55(f)	Safety point 3	111
4.55(g)	Safety point 4	112
4.55(h)	Point 2	112
4.55(i)	Safety point 5	113
4.55(j)	Point 3	113
4.55(k)	Safety point 6	114
4.55(l)	Point 4	114
4.55(m)	Safety point 7	115

4.55(n)	Safety point 8	115
4.55(o)	Point 5	116
4.55(p)	End point	116
4.55(q)	Home position	117
4.56(a)	Graph of joint value versus time for joint 1 with 20 % speed(r)	120
4.56(c)	Graph of velocity versus time for joint 1 with 20 % speed	120
4.56(b)	Graph of acceleration versus time for joint 1 with 20 % speed	121
4.57(a)	Graph of joint value versus time for joint 2 with 20 % speed	123
4.57(b)	Graph of velocity versus time for joint 2 with 20 % speed	123
4.57(c)	Graph of acceleration versus time for joint 2 with 20 % speed	124
4.58(a)	Graph of joint value versus time for joint 3 with 20 % speed	126
4.58(b)	Graph of velocity versus time for joint 3 with 20 % speed	126
4.58(c)	Graph of acceleration versus time for joint 3 with 20 % speed	127
4.59(a)	Graph of joint value versus time for joint 4 with 20 % speed	129
4.59(b)	Graph of velocity versus time for joint 4 with 20 % speed	129
4.59(c)	Graph of acceleration versus time for joint 4 with 20 % speed	130
4.60(a)	Graph of joint value versus time for joint 5 with 20 % speed	132
4.60(b)	Graph of velocity versus time for joint 5 with 20 % speed	132
4.60(c)	Graph of acceleration versus time for joint 5 with 20 % speed	133
4.61(a)	Graph of joint value versus time for joint 6 with 20 % speed	135
4.61(b)	Graph of velocity versus time for joint 6 with 20 % speed	135
4.61(c)	Graph of acceleration versus time for joint 6 with 20 % speed	136
4.62	Graph of all joint position in real simulation with 20 % speed	138
4.63(a)	Graph of joint value versus time for joint 1 with 30 % speed	138
4.63(b)	Graph of velocity versus time for joint 1 with 30 % speed	139
4.63(c)	Graph of acceleration versus time for joint 1 with 30 % speed	141
4.64(a)	Graph of joint value versus time for joint 2 with 30 % speed	141
4.64(b)	Graph of velocity versus time for joint 2 with 30 % speed	142
4.64(c)	Graph of acceleration versus time for joint 2 with 30 % speed	144
4.65(a)	Graph of joint value versus time for joint 3 with 30 % speed	144
4.65(b)	Graph of velocity versus time for joint 3 with 30 % speed	145
4.65(c)	Graph of acceleration versus time for joint 3 with 30 % speed	147

LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

°	-	Degree
CSO	-	Configuration space obstacle
Deg	-	Degree
DOF	-	Degree of freedom
K-Chart	-	Khazani Chart
$q(t)$	-	A trajectory is a function of time

CHAPTER 1
INTRODUCTION

1.1 Background

Nowadays in many factories, human power is still being used to do the final inspection for the quality control. As human, they cannot avoid mistakes in their work. This is because human can get tired after sometime, cannot focus on the repeating work and the most important is, they cannot achieve the ability as the robot does, that is, they are slower than robot. Moreover, human expert are difficult to find or maintain in an industry, require training and their skills may take time to develop. There are also cases where inspection tends to be tedious or difficult, even for the best-trained expert (Malamas, 2005).

1.1.1 The industrial vision inspection system evolution

Figure 1.1 shows how the evolution occur. Early before 1980's, the industries throughout the world still using human power to do the inspection process in factories. Fabel (1997) wrote that, the evolution start in 1980's ,after the machine vision was first marketed as a new, must-see technology for manufacturing automation. Then when robot was introduced in 1960's, the development of robot had also bring a development in machine vision system industry. Nowadays, people around the world had widely use the robot-controlled vision inspection system in their factory, to get more advantage. Figure 1.2 shows a typical industry vision system and Figure 1.3 shows a robot-controlled vision inspection system.

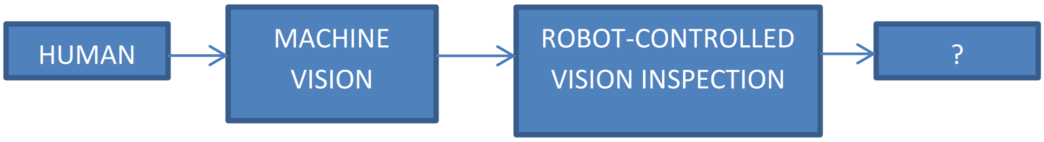

Figure 1.1: The machine vision inspection system evolution

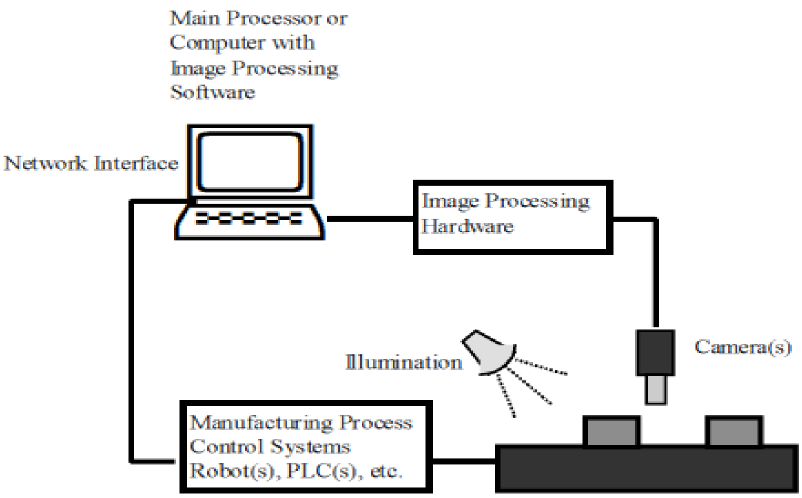

Figure 1.2: A typical industrial vision sytem. (Malamas, 2005).

Figure 1.3: A robot-controlled vision inspection sytem (Cognex Corporation, 2013)

1.2 Problem Statement

A typical industrial vision system is good, but the problem is some of the vision machine is not mobile and the capturing width is limited to certain angle. To overcome this problem, robot-controlled vision inspection system can be used. The idea is to attach the camera on the tip of the robot, so that the robot will move the camera and the camera will capture the image of the part. If any defect is detected from the image, image processing device will send signal to the output device so that the product will be categorized as "Not Good". This research study is very important to make sure that the robot will do the best movement which consist of the consideration of its position, velocity and acceleration during the inspection process .

1.3 Objective

The objective of this project is to estimate the best configuration workspace for a robot - controlled vision inspection system, by considering the position, velocity, acceleration, capability to avoid obstacles, and cycle time of the robot.