

**DESIGN AND DEVELOPMENT OF A FLEXIBLE
ROBOTIC ARM VISION SYSTEM FOR
ORTHOPEDIC ROBOT**



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UNIVERSITI MALAYSIA SABAH

**SCHOOL OF ENGINEERING AND
INFORMATION TECHNOLOGY
UNIVERSITI MALAYSIA SABAH
2012**

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ROBOTIC ARM VISION SYSTEM FOR
ORTHOPEDIC ROBOT**

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**THIS IS SUBMITTED IN FULFILLMENT FOR
THE DEGREE OF MASTER OF SCIENCE**

**SCHOOL OF ENGINEERING AND
INFORMATION TECHNOLOGY
UNIVERSITI MALAYSIA SABAH
2012**

DECLARATION

I hereby declare that the materials in this thesis is my own except for quotations, excerpts, equations, summaries and references, which have been duly acknowledged.

16 July 2012

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PK2009-8068



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TABLE OF CONTENTS

	Page
TITLE	i
DECLARATION	ii
CERTIFICATION	iii
ACKNOWLEDGEMENT	iv
ABSTRACT	v
ABSTRAK	vi
TABLE OF CONTENTS	vii
LIST OF TABLES	ix
LIST OF FIGURES	x
LIST OF ABBREVIATIONS	xx
CHAPTER 1: INTRODUCTION	1
1.1 Robot	1
1.2 Medical Robotics	2
1.3 Research Motivation	5
1.4 Research Objectives	8
1.5 Research Scope	8
1.6 Thesis Organization	9
CHAPTER 2: LITERATURE REVIEW	11
2.1 Introduction	11
2.2 Telemedicine	11
2.3 Healthcare Robots	14
2.3.1 Telemonitoring / Telerounding Robots	14
2.3.2 Surgical Robots	15
2.3.3 Assistive/ Rehabilitation Robots	17
2.3.4 Robotic Prosthetic	20
2.4 Robotic Arm	22
2.5 Robotic Vision system	26
2.6 Artificial Intelligence in robots	26
2.6.1 Fuzzy Logic	28
2.7 Chapter Summary	29
CHAPTER 3: METHODOLOGY	30
3.1 Introduction	30
3.2 Flexible Robotic Arm Design and Architecture	30
3.3 DC Motors	33
3.4 Motor Drivers	34
3.5 Servos	35
3.6 Sensors	36
3.7 Encoders	38
3.8 Microcontrollers	40
3.9 Hardware and Software Communication	41
3.9.1 Universal serial Bus (USB)	42
3.9.2 Serial Peripheral Interface (SPI™)	43

3.9.3	Inter-Integrated Circuit (I ² C™)	44
3.10	Flexible Robotic arm Control Algorithm	45
3.11	Chapter Summary	46
CHAPTER 4: HARDWARE DEVELOPMENT		48
4.1	Introduction	48
4.2	Design Criteria	48
4.3	Robotic Arm Mechanical Design	49
4.4	Prototype Development	51
4.5	Electrical and Electronic Details	55
4.5.1	Motor Driver Connection	57
4.5.2	Motor Encoder Connection	58
4.5.3	Servo Connection	59
4.5.4	Monitor screen Tilt control	59
4.6	Vision and Lighting System	60
4.7	Sensor Array	62
4.8	Communication Circuit	64
4.9	Software Development Tools	66
4.10	Flexible Robotic Arm Standalone System	67
4.11	Flexible Robotic Arm Graphical User Interface (GUI)	69
4.12	Overview of Flexible Robotic Arm Integrated with OTOROB	71
4.13	Chapter Summary	73
CHAPTER 5: SAFETY SYSTEM OF FLEXIBLE ROBOTIC ARM		75
5.1	Introduction	75
5.2	Danger Monitoring System (DMS)	75
5.2.1	DMS for Obstacle Avoidance	76
5.2.2	DMS for Fail Safe System	80
5.3	Obstacle Avoidance System (OAS)	83
5.4	Fail Safe and Auto Recovery System (FSARS)	84
5.5	Chapter Summary	88
CHAPTER 6: RESULTS AND DISCUSSION		89
6.1	Introduction	89
6.2	Robotic Arm Mechanical Design Analysis	89
6.2.1	Stress-Strain Analysis	90
6.2.2	Displacement Analysis	100
6.3	Articulation and Control of Flexible Robotic Arm	102
6.4	Vision and Lighting System	108
6.5	Execution of Danger Monitoring System (DMS)	110
6.5.1	DMS for obstacle avoidance	110
6.6	Execution of Obstacle Avoidance System (OAS)	115
6.7	Execution of Fail Safe and Auto-Recovery System (FS-ARS)	120
6.8	Chapter Summary	121
CHAPTER 7: CONCLUSION		119
8.1	Research Summary	119
8.2	Suggestion for Future Studies	120

REFERENCES	125
APPENDIX	132
APPENDIX A	132
APPENDIX B	133
APPENDIX C	146



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LIST OF ABBREVIATION

°	Degree
CAD	Computer Aided Design
CCD	Charge-Coupled Device
cm	Centimetre
DC	Direct current
DMS	Danger Monitoring System
F	Far
FL	Fuzzy Logic
FSARS	Fail Safe and Auto Recovery System
GUI	Graphical User Interface
HS	High speed
I ² C	Inter-Integrated Circuit
LED	Light Emitting Diode
LS	Low speed
m	Metre
mm	Millimetre
M	Medium
MS	Medium speed
MSB	Most Significant Bit
N	Near
OAS	Obstacle Avoidance System
OTOROB	Orthopaedic robot
PIC	Programmable Integrated Circuit
QEI	Quadrature Encoder Interface
RAM	Random Access Memory
RPM	Revolutions per minute
SPI	Serial Peripheral Interface

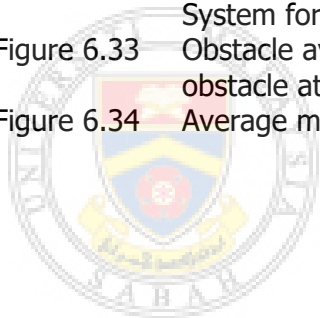
LIST OF FIGURES

		Page
Figure 1.1	Sketch of Automata of Al-Jazari (A) and ASIMO the humanoid robot by Honda (B)	1
Figure 1.2	Da Vinci (A) and Zues (B) surgical robots	4
Figure 1.3	Telerounding by a remote doctor using RP7 robot in Shawne Mission Medical Centre, Kansas City	4
Figure 1.4	Orthopedic Robot (OTOROB)	7
Figure 2.1	An inmate gets an ear exam with a remote doctor by utilizing medical audio-visual tools from AMD Global Telemedicine	12
Figure 2.2	Penn State students travelled to Kenya, where they introduced telemedicine as a way to improve health care in rural areas.	13
Figure 2.3	Telerobot for assistance (A) and Remote Presence-7 for hospital telerounding use (B)	15
Figure 2.4	Lindberg minimal invasive surgery cholecystectomy (surgical removal of the gallbladder) at Stransbourg Civil Hospital, in Eastern France	16
Figure 2.5	The HEXORR (A) and HWARD (B) exoskeletal rehabilitation robots	18
Figure 2.6	iRobi a multi-dimensional emotional robot (A) and AIBO the robotic dog (B)	18
Figure 2.7	Hybrid Assistive Limb suite (HAL-5) (A) and Wilmington robotic exoskeleton (WREX) (B) mounted on a wheel chair	19
Figure 2.8	MANUS-HAND (left) for upper limb amputees and DEKA arm for arm amputees	21
Figure 2.9	Self-contained powered knee and ankle trans femoral prosthesis (A) and powered ankle-foot prosthesis (B) for ankle amputees	22
Figure 2.10	Robotic arm in manufacturing sector for welding	22
Figure 2.11	Da Vinci telesurgical robot operated by a remote surgeon on real patient	23
Figure 2.12	Mitsubishi PA-10 industrial robot integrated with teleultrasound system	25
Figure 2.13	Seven DOF cable-driven robotic arm (CDRA)	25
Figure 2.14	Fuzzy Logic model	28
Figure 3.1	Position of flexible robotic arm at docking/original position within the robot dimension	31
Figure 3.2	Region enclosed by the working envelope of the robotic arm with a standard 2m x 0.9m hospital bed as reference	31
Figure 3.3	Side view of camera (with zoom feature) coverage envelope with a standard hospital bed	32
Figure 3.4	Three-dimensional coverage of combined mechanical arm and camera projection	33

Figure 3.5	DC geared motor unit used in the development of flexible robotic arm	34
Figure 3.6	MD10C motor driver used to control main motors of flexible robotic arm	35
Figure 3.7	Hitec HSR5980SG digital servo with metal gear	36
Figure 3.8	LV-MaxSonar®-EZ1™ High Performance Sonar Range Finder	37
Figure 3.9	Beam characteristic of the LV-MaxSonar®-EZ1™	38
Figure 3.10	QEI with the DC geared motor package	39
Figure 3.11	Square quadrature waveform of channel A and channel B of the encoder	39
Figure 3.12	State diagram of QEI encoder	40
Figure 3.13	PIC18f4550 from Microchip	41
Figure 3.14	The hardware and software communication module of flexible robotic arm	42
Figure 3.15	The USB topology is a "tiered star"	43
Figure 3.16	Connection between two microcontrollers in master/slave relationship	44
Figure 3.17	I ² C communication connections between a master device and two slave devices	45
Figure 3.18	Control algorithm of flexible robotic arm	46
Figure 4.1	Flexible robotic arm model developed using Solidworks	49
Figure 4.2	First arm extension and camera on second arm extension are enclosed within robotic arm platform	50
Figure 4.3	Half extension of flexible robotic arm where the first arm extension still at the docking position	50
Figure 4.4	Maximum extension of flexible robotic arm	51
Figure 4.5	Flexible robotic arm at docking position (A), projection of first arm extension (B) and projection of both first and second arms extension (C)	52
Figure 4.6	Servo mounting for yaw motion (A) and servo mounting for pitch motion (B)	53
Figure 4.7	Rack and pinion mounting on the first extension arm to provide linear motion	53
Figure 4.8	Rack and pinion joint on the second extension arm to provide linear motion	54
Figure 4.9	Nylon block and aluminium rod mounting to provide linear support for first extension arm	54
Figure 4.10	Linear rail mounting to provide linear motion support for second extension arm	55
Figure 4.11	Flexible robotic arm control circuit Part 1	56
Figure 4.12	Flexible robotic arm control circuit Part 2	56
Figure 4.13	Motor driver connections on Slave PIC	58
Figure 4.14	Motor encoder connections on Slave PIC	58
Figure 4.15	Yaw and pitch servo connections to PIC	59
Figure 4.16	Monitor screen tilt control circuit	60
Figure 4.17	CCD camera mounting on flexible robotic arm	61
Figure 4.18	Integration of super bright LEDs in the CCD camera Unit	61
Figure 4.19	Lighting control circuit	62

Figure 4.20	Bottom view of sensor placement under the flexible robotic arm unit	62
Figure 4.21	Isometric view of sensor placement in robotic arm	63
Figure 4.22	Sensors coverage area from top view	63
Figure 4.23	Sensors connection on PIC	64
Figure 4.24	PS2 controller wires colour coding	65
Figure 4.25	USB and PS2 serial communications	65
Figure 4.26	I ² C communication circuit between a Master and Slave Microcontroller	66
Figure 4.27	Flexible robotic arm standalone system control execution	67
Figure 4.28	PS2 controller button mapping for flexible robotic arm Control	68
Figure 4.29	GUI for flexible robotic arm standalone control	69
Figure 4.30	OTOROB control flow	72
Figure 5.1	Control flow of DMS for obstacle avoidance	76
Figure 5.2	DMS danger level zone classification	77
Figure 5.3	Sensor associated to stroke length	78
Figure 5.4	Danger Monitoring System panel	79
Figure 5.5	DMS for fail safe	80
Figure 5.6	GUI for arm stroke displacement	81
Figure 5.7	GUI warning indicator of DMS for fail safe	82
Figure 5.8	DMS execution zone	83
Figure 5.9	Fuzzy logic model for Obstacle Avoidance System	84
Figure 5.10	FSARS flow control of flexible robotic arm	86
Figure 5.11	First extension limit sensor (A) and second extension limit sensor (B)	87
Figure 5.12	Docking limit sensor for first extension arm (A) and docking limit sensor for second extension arm (B)	87
Figure 6.1	Flexible robotic arm assembly	90
Figure 6.2	Stress analysis conducted on extension rail at docking state without roller support	91
Figure 6.3	Stress analysis conducted on extension rail at half (50%) stroke length without roller support	91
Figure 6.4	Stress analysis conducted on extension rail at full (100%) stroke length without roller support	92
Figure 6.5	Stress analysis conducted on extension rail at docking state with roller support	93
Figure 6.6	Stress analysis conducted on extension rail at half (50%) stroke length with roller support	93
Figure 6.7	Stress analysis conducted on extension rail full (100%) stroke length with roller support	94
Figure 6.8	Stress analysis with and without roller support	94
Figure 6.9	Strain analysis of extension rail with and without roller support	95
Figure 6.10	Stress analysis of nylon slider at docking state	97
Figure 6.11	Stress analysis of nylon slider at half extension (50%)	97
Figure 6.12	Stress analysis of nylon slider at full extension (100%)	98
Figure 6.13	Stress analysis of nylon slider	98
Figure 6.14	Strain analysis of nylon slider	99

Figure 6.15	Stress analysis of robotic arm platform	99
Figure 6.16	Strain analysis of robotic arm platform	100
Figure 6.17	Displacement analysis of extension rail	101
Figure 6.18	Displacement analysis of nylon slider	102
Figure 6.19	Experimental setup of linear displacement analysis	103
Figure 6.20	Linear displacement versus time taken	104
Figure 6.21	Linear velocity versus time taken	106
Figure 6.22	Angular velocity of rotational motor	108
Figure 6.23	Pictures taken at different light intensities and corresponding pixel distribution range	109
Figure 6.24	Active sensor monitoring at robotic arm stroke 25cm	111
Figure 6.25	Rule viewer of first level DMS fuzzification	112
Figure 6.26	Surface plot of first level DMS defuzzification	112
Figure 6.27	Second level DMS fuzzification rule viewer	113
Figure 6.28	Second level DMS defuzzification	114
Figure 6.29	Danger monitoring panel obstacle and danger level indicator	114
Figure 6.30	Control freedom and control restriction corresponding to the obstacle	115
Figure 6.31	Fuzzy rule set of OAS for linear movement	116
Figure 6.32	Surface plot of flexible robotic arm Obstacle Avoidance System for linear movement	117
Figure 6.33	Obstacle avoidance pattern of flexible robotic arm against obstacle at various positions	118
Figure 6.34	Average motor speed against subjected obstacle	119



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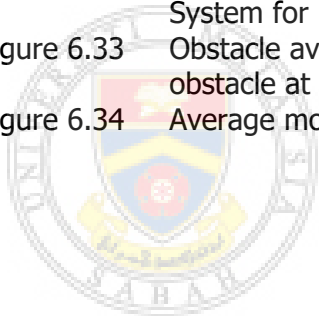
LIST OF FIGURES

		Page
Figure 1.1	Sketch of Automata of Al-Jazari (A) and ASIMO the humanoid robot by Honda (B)	1
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Figure 2.1	An inmate gets an ear exam with a remote doctor by utilizing medical audio-visual tools from AMD Global Telemedicine	12
Figure 2.2	Penn State students travelled to Kenya, where they introduced telemedicine as a way to improve health care in rural areas.	13
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Figure 2.5	The HEXORR (A) and HWARD (B) exoskeletal rehabilitation robots	18
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Figure 2.8	MANUS-HAND (left) for upper limb amputees and DEKA arm for arm amputees	21
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Figure 3.2	Region enclosed by the working envelope of the robotic arm with a standard 2m x 0.9m hospital bed as reference	31
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Figure 3.6	MD10C motor driver used to control main motors of flexible robotic arm	35
Figure 3.7	Hitec HSR5980SG digital servo with metal gear	36
Figure 3.8	LV-MaxSonar®-EZ1™ High Performance Sonar Range Finder	37
Figure 3.9	Beam characteristic of the LV-MaxSonar®-EZ1™	38
Figure 3.10	QEI with the DC geared motor package	39
Figure 3.11	Square quadrature waveform of channel A and channel B of the encoder	39
Figure 3.12	State diagram of QEI encoder	40
Figure 3.13	PIC18f4550 from Microchip	41
Figure 3.14	The hardware and software communication module of flexible robotic arm	42
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Figure 3.16	Connection between two microcontrollers in master/slave relationship	44
Figure 3.17	I ² C communication connections between a master device and two slave devices	45
Figure 3.18	Control algorithm of flexible robotic arm	46
Figure 4.1	Flexible robotic arm model developed using Solidworks	49
Figure 4.2	First arm extension and camera on second arm extension are enclosed within robotic arm platform	50
Figure 4.3	Half extension of flexible robotic arm where the first arm extension still at the docking position	50
Figure 4.4	Maximum extension of flexible robotic arm	51
Figure 4.5	Flexible robotic arm at docking position (A), projection of first arm extension (B) and projection of both first and second arms extension (C)	52
Figure 4.6	Servo mounting for yaw motion (A) and servo mounting for pitch motion (B)	53
Figure 4.7	Rack and pinion mounting on the first extension arm to provide linear motion	53
Figure 4.8	Rack and pinion joint on the second extension arm to provide linear motion	54
Figure 4.9	Nylon block and aluminium rod mounting to provide linear support for first extension arm	54
Figure 4.10	Linear rail mounting to provide linear motion support for second extension arm	55
Figure 4.11	Flexible robotic arm control circuit Part 1	56
Figure 4.12	Flexible robotic arm control circuit Part 2	56
Figure 4.13	Motor driver connections on Slave PIC	58
Figure 4.14	Motor encoder connections on Slave PIC	58
Figure 4.15	Yaw and pitch servo connections to PIC	59
Figure 4.16	Monitor screen tilt control circuit	60
Figure 4.17	CCD camera mounting on flexible robotic arm	61
Figure 4.18	Integration of super bright LEDs in the CCD camera Unit	61
Figure 4.19	Lighting control circuit	62

Figure 4.20	Bottom view of sensor placement under the flexible robotic arm unit	62
Figure 4.21	Isometric view of sensor placement in robotic arm	63
Figure 4.22	Sensors coverage area from top view	63
Figure 4.23	Sensors connection on PIC	64
Figure 4.24	PS2 controller wires colour coding	65
Figure 4.25	USB and PS2 serial communications	65
Figure 4.26	I ² C communication circuit between a Master and Slave Microcontroller	66
Figure 4.27	Flexible robotic arm standalone system control execution	67
Figure 4.28	PS2 controller button mapping for flexible robotic arm Control	68
Figure 4.29	GUI for flexible robotic arm standalone control	69
Figure 4.30	OTOROB control flow	72
Figure 5.1	Control flow of DMS for obstacle avoidance	76
Figure 5.2	DMS danger level zone classification	77
Figure 5.3	Sensor associated to stroke length	78
Figure 5.4	Danger Monitoring System panel	79
Figure 5.5	DMS for fail safe	80
Figure 5.6	GUI for arm stroke displacement	81
Figure 5.7	GUI warning indicator of DMS for fail safe	82
Figure 5.8	DMS execution zone	83
Figure 5.9	Fuzzy logic model for Obstacle Avoidance System	84
Figure 5.10	FSARS flow control of flexible robotic arm	86
Figure 5.11	First extension limit sensor (A) and second extension limit sensor (B)	87
Figure 5.12	Docking limit sensor for first extension arm (A) and docking limit sensor for second extension arm (B)	87
Figure 6.1	Flexible robotic arm assembly	90
Figure 6.2	Stress analysis conducted on extension rail at docking state without roller support	91
Figure 6.3	Stress analysis conducted on extension rail at half (50%) stroke length without roller support	91
Figure 6.4	Stress analysis conducted on extension rail at full (100%) stroke length without roller support	92
Figure 6.5	Stress analysis conducted on extension rail at docking state with roller support	93
Figure 6.6	Stress analysis conducted on extension rail at half (50%) stroke length with roller support	93
Figure 6.7	Stress analysis conducted on extension rail full (100%) stroke length with roller support	94
Figure 6.8	Stress analysis with and without roller support	94
Figure 6.9	Strain analysis of extension rail with and without roller support	95
Figure 6.10	Stress analysis of nylon slider at docking state	97
Figure 6.11	Stress analysis of nylon slider at half extension (50%)	97
Figure 6.12	Stress analysis of nylon slider at full extension (100%)	98
Figure 6.13	Stress analysis of nylon slider	98
Figure 6.14	Strain analysis of nylon slider	99

Figure 6.15	Stress analysis of robotic arm platform	99
Figure 6.16	Strain analysis of robotic arm platform	100
Figure 6.17	Displacement analysis of extension rail	101
Figure 6.18	Displacement analysis of nylon slider	102
Figure 6.19	Experimental setup of linear displacement analysis	103
Figure 6.20	Linear displacement versus time taken	104
Figure 6.21	Linear velocity versus time taken	106
Figure 6.22	Angular velocity of rotational motor	108
Figure 6.23	Pictures taken at different light intensities and corresponding pixel distribution range	109
Figure 6.24	Active sensor monitoring at robotic arm stroke 25cm	111
Figure 6.25	Rule viewer of first level DMS fuzzification	112
Figure 6.26	Surface plot of first level DMS defuzzification	112
Figure 6.27	Second level DMS fuzzification rule viewer	113
Figure 6.28	Second level DMS defuzzification	114
Figure 6.29	Danger monitoring panel obstacle and danger level indicator	114
Figure 6.30	Control freedom and control restriction corresponding to the obstacle	115
Figure 6.31	Fuzzy rule set of OAS for linear movement	116
Figure 6.32	Surface plot of flexible robotic arm Obstacle Avoidance System for linear movement	117
Figure 6.33	Obstacle avoidance pattern of flexible robotic arm against obstacle at various positions	118
Figure 6.34	Average motor speed against subjected obstacle	119



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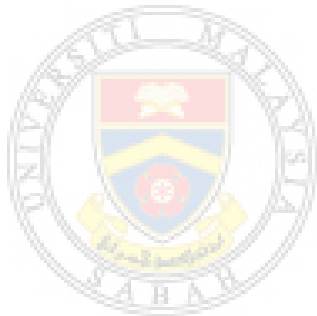
LIST OF TABLES

		Page
Table 1.1	Road accidents statistics from year 2003 to 2010	5
Table 4.1	Truth table of MD10C motor driver controller	57
Table 4.2	PS2 button press and robotic arm control execution	68
Table 4.3	Key press associated with the robotic arm control	70
Table 4.4	Two ways signal/data execution and acquisition between OTOROB and command centre	73
Table 5.1	Crisp input representing obstacle distance	77
Table 5.2	First level fuzzy engine inference system for left coverage area (sensor #3 and sensor #4)	78
Table 5.3	Fuzzy logic rule table for DMS	79
Table 5.4	Fuzzy rule table for OAS	85
Table 6.1	Stroke length and torque of robotic arm	96
Table 6.2	Time taken to reach different linear distance (cm)	104
Table 6.3	Standard deviation and error percentage of linear displacement	105
Table 6.4	Linear velocity at different points in linear motion	105
Table 6.5	Average speed, standard deviation and error percentage of linear displacement	106
Table 6.6	Angular displacement and time taken at various stroke length	107
Table 6.7	Angular velocity, standard deviation and error percentage at different stroke length of robotic arm	107
Table 6.8	Angular velocity and linear velocity subjected to different obstacle speed	119
Table 6.9	FSARS testing subjected to different limit sensor input	120

ACKNOWLEDGEMENT

This research project would not have been possible without the support of many people. I wish to express my gratitude to my supervisor, Engr. Dr. Muralindran Mariappan who was abundantly helpful and offered invaluable assistance, support and guidance. Deepest gratitude is also to the members of the Robotics and Biomedical Research Group (RoBiMED) members, Mr. R.Vigneswaran, Mr. Kumareshan, Mr. Brandon Khoo and Mr. Choo Chee Wee. I would also like to convey thanks to the School of Engineering Information Technology, for providing the laboratory and equipment facilities. Then, I also wish to thank Prof. Dr. Ravindra Pogaku for taking endless initiatives to provide postgraduate students other facilities and support. Not forgotten, lab assistant, Mr. Irwan Baharudzaman for his support to the research. I also wishes to express my love and gratitude to my beloved families; for their understanding and endless love, through the duration of my studies.

Thayabaren Ganesan
16 July 2012



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ABSTRAK

Salah satu masalah utama dan terbaru yang membelunggu hospital di Malaysia adalah masalah kekurangan pakar atau pakar bedah, terutamanya di kawasan luar bandar. Pakar bedah khusus yang tidak mencukupi di kawasan-kawasan itu terutamanya dalam bidang ortopedik menyebabkan lebih banyak kematian di kalangan pesakit disebabkan oleh kekangan masa. Sistem robot mudah alih yang dikenali sebagai OTOROB telah direka dan dibangunkan untuk membantu pakar bedah untuk hadir secara maya di kawasan itu bagi menghadiri pesakit. Sistem robot mudah alih tersebut memerlukan lengan robotik yang fleksibel untuk memeriksa pesakit yang dikawal dari jauh oleh pakar bedah. Lengan robot yang fleksibel dengan sistem penglihatan sebagai effector akhir telah direka, dirumuskan dan diuji pada masa nyata. Sebelum pembangunan prototaip, pemodelan maya lengan robot dilakukan menggunakan perisian Solidworks. Model yang direka telah disimulasi dan dianalisis untuk mengkaji kesesuaian reka bentuk. Keputusan simulasi membuktikan bahawa reka bentuk berkenaan sesuai untuk dibangunkan. Kemudian, prototaip yang dibangunkan telah diuji kebolehulangan, dan ujian kelinearan untuk menentukan kawalan pergerakan lengan robot. Analisis kelinearan dan sudut pergerakan lengan robot menunjukkan ralat kurang daripada 5% kesilapan. Perisian pengawalan lengan robotic (GUI) telah dibangunkan untuk mengawal lengan robot dan mendapatkan data dari lengan robot mengenai orientasi dan kedudukan. Logik kabur dilaksanakan dalam sistem kawalan keselamatan untuk artikulasi lengan robot. Sistem keselamatan lengan robot terdiri daripada Sistem Pemantauan Bahaya (DMS), Sistem Pengelakan Rintangan (OAS) dan Sistem Gagal Selamat dan Pemulihan Sendiri (FSARS). DMS yang dikawal system logic kabur diuji dan dinilai. Hasil kajian menunjukkan bahawa DMS mampu menilai and menunjukkan tahap bahaya di sekeliling lengan robotik kepada pengguna melalui GUI dengan tanda-tanda amaran dan kedudukan halangan. Kemudian, OAS memberikan maklum balas kepada halangan mobil dan statik di sekeliling lengan robot. Lengan robot didapati mampu mengelakkan halangan menghampiri secara autonomi melalui kawalan logik kabur. FSARS lengan robot adalah tertakluk kepada pelbagai keadaan kegagalan, dan sistem membuktikan bahawa penggunaan sistem pemulihan berjaya. Akhirnya, sistem penglihatan dinilai dengan menganalisis sistem pencahayaan pengelihatan menggunakan perisian Matlab. Integrasi sistem lampu LED meningkatkan kejelasan visual yang diperolehi melalui kamera video. Kawalan lancar lengan robotik dan juga rutin keselamatan melalui logik kabur telah menambah baik keseluruhan artikulasi lengan robotik.

ABSTRACT

DESIGN AND DEVELOPMENT OF A FLEXIBLE ROBOTIC ARM VISION SYSTEM FOR ORTHOPAEDIC ROBOT (OTOROB)

One of the main and recent problems in Malaysian hospitals is the lack of surgeons and specialists, especially in rural areas. Insufficient specialised surgeons in such regions particularly in the niche of orthopaedic causes more fatalities and amputees due to time constrain in attending the patients. Broken limbs due to accidents can be treated and recovered. But severed blood vessels results in blood loss and leads to amputation or even worst fatalities. A mobile robotic system known as OTOROB is designed and developed to aid orthopaedic surgeons to be virtually present at such areas for attending patients. The developed mobile robotic platform requires a flexible robotic arm vision system to be controlled remotely by the surgeon. To be present virtually is still insufficient if clearer view is not obtained. Thus, a flexible robotic arm with vision system as end effector is designed, developed and tested in real time. Prior to the development of the prototype, virtual modelling of the robotic arm is done in Solidworks. The designed model is simulated and analysed to study the suitability of the design. The simulation results proved that the design is applicable. Then, the developed prototype is subjected to repeatability, and linearity tests in order to determine the movement control of the robotic arm. The robotic arm linear and angular movements resulted in less than 5% of error. A Graphical User Interface (GUI) is developed to control the robotic arm and obtain data from the robotic arm regarding the orientation and position. Fuzzy logic is implemented in the control system to provide safety for the robotic arm articulation. The safety systems of the robotic arm consist of Danger Monitoring System (DMS), Obstacle Avoidance System (OAS) and Fail Safe and Auto Recovery System (FSARS). The fuzzy controlled DMS system was tested and evaluated. The results prove that the DMS is capable of conveying danger level surrounding the robotic arm to the user through GUI with warning indication and obstacle positions. While, the developed OAS, responded to the approaching and static obstacle around the robotic arm. The robotic arm is capable of avoiding approaching obstacle autonomously via fuzzy control. FSARS of the robotic arm was subjected to various failure circumstances and the system executed the recovery system successfully. Finally, the vision system was evaluated by analysing the vision lighting system using Matlab software. The integration of LED lighting system improved the visual clarity obtained through the video camera. The smooth control of the robotic arm coupled with the safety routines improved the overall articulation of the robotic arm.

CHAPTER 1

INTRODUCTION

1.1 Robot

The advancement of human civilization aside from those core elements such as agriculture, trade, transportation, architecture, mathematics, science, politics, and astronomy has brought human kind into a new era of sophisticated and modern living. The use of tools and “know-how-to-make” ability of human marked the beginning of technology, or the science of engineering which have brought mankind into a new era of highly sophisticated and advance civilization, where in this 21st century robotics play a major role (Mitsuishi *et al.*, 2007).

The early development of robot can date back to 12th century AD, such as the Automata of Al-Jazari, which is a self-operating machine and Leonardo Da Vinci’s humanoid automaton in the 15th century (Vijay Kumar, 2010). Since then robots also evolved on the path of human civilization until the development of the world most advanced humanoid robots like ASIMO by Honda and TOPIO by Tosy Robotics. Automata of Al-Jazari and ASIMO are shown in Figure 1.1.

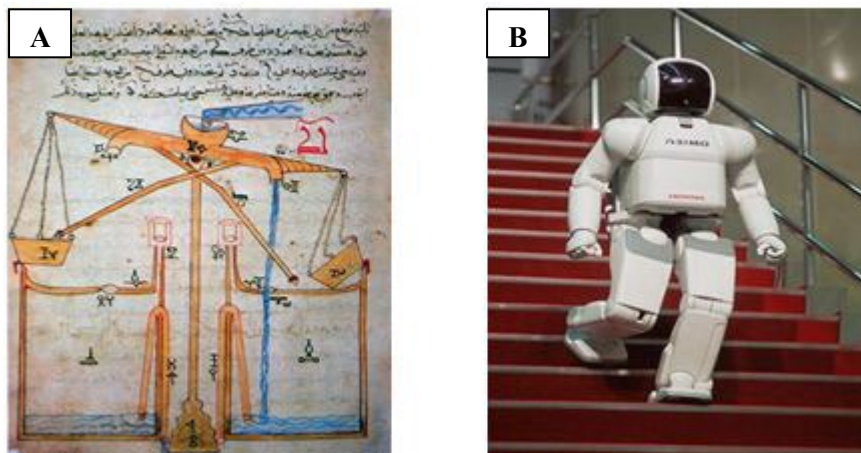


Figure 1.1: Sketch of Automata of Al-Jazari (A) and ASIMO the humanoid robot by Honda (B)

Source: (A) www.wikipedia.org/wiki/Al-Jazari and (B) asimo.honda.com/products

A robot in modern world according to Robot Institute of America is an automatic, reprogrammable, multifunctional manipulator designed to move materials, parts, tools or specialized devices through various programmed motions for the performance of variety of tasks (Robot Institute of America, 1975). While, Broadbent *et al.* (2009) described a robot as a very powerful computer with equally powerful software housed in a mobile body and able to act rationally on its perception of the world around it. Robots were initially used in the automation sector to replace human labours for handling repetitive and simple tasks reliably, with the objective of cost reduction (Haydars and Levent, 2007).

Besides that, wide application of robots include deployment in dangerous and hazardous work spaces which are potentially dangerous to humans, such as underwater, underground, space and other extreme environments (Park *et al.*, 2006). The usage of robots can be traced in almost every field ventured by humans, from household robots such as vacuum cleaner robots to bomb disposing robots in military operations and NASA Spirit Rover for Mars exploration.

However, the new trends in robotics research have been denominated by service robotics because of their general goal of getting robots closer to human social needs, especially in the areas such as medical robotics, rehabilitation robotics, field robotics, construction robotics and humanoid robotics (Garcia *et al.*, 2007).

1.2 Medical Robotics

Medical robotics refers to robotic systems applied within the domain of health care which evolved from multidisciplinary field of science and engineering involving topics from mechanical engineering, electrical engineering, materials science and computer science (Wang *et al.*, 2006).

Initial surgical robotic systems in the 1980s employed general-purpose industrial manipulators, either directly or with minor modifications (Taylor and Stoianovici, 2003). The designed robotic system often shares its working area with

operators or medical staff and has a close interaction with the patient (Vilchis *et al.*, 2003).

According to Kanade *et al.* (2006) and Taylor (2006), the term medical robotics has often been construed to refer strictly to surgical procedures. However due to its indefatigability, accuracy, and repeatability, robotic technology is increasingly affecting the entire healthcare sector through advances in surgery, diagnosis, preoperative planning, postoperative evaluation, chronic assistive devices, acute rehabilitation, hospital logistics and scheduling, long-term follow-up and quality control.

Medical robotics also extensively improves existing medical procedures to be less invasive and produce fewer side effects that would result in faster recovery times and improved worker productivity, improve risk-benefit, cost-benefit ratios and reduced medical errors (Okamura *et al.*, 2010). The major niche in medicine that employs robotics is surgical and interventional robotics. The development of surgical robots is motivated by the desire to enhance the effectiveness of a procedure by coupling information to action in the operating room or interventional suite and transcend human physical limitations in performing surgery and other interventional procedures (Wang *et al.*, 2006). The earlier surgical robots were used in neurosurgery and orthopaedic surgery as the anatomic landmarks provided convenient, fixed and accurate points of registration by the computer (Hong *et al.*, 2006).

The Zeus and da Vinci robots are robots with master-slave configuration where the surgeon controls the surgery and a set of positioners and camera-control equipment that is mounted on the operating room table are used effectively in telesurgery (Butner and Ghodoussi, 2003; Mitsuishi *et al.*, 2007). Surgical robots such as the da Vinci surgical system and Zeus surgical system shown in Figure 1.2, are beginning to realize their potential in terms of improved patient outcomes.

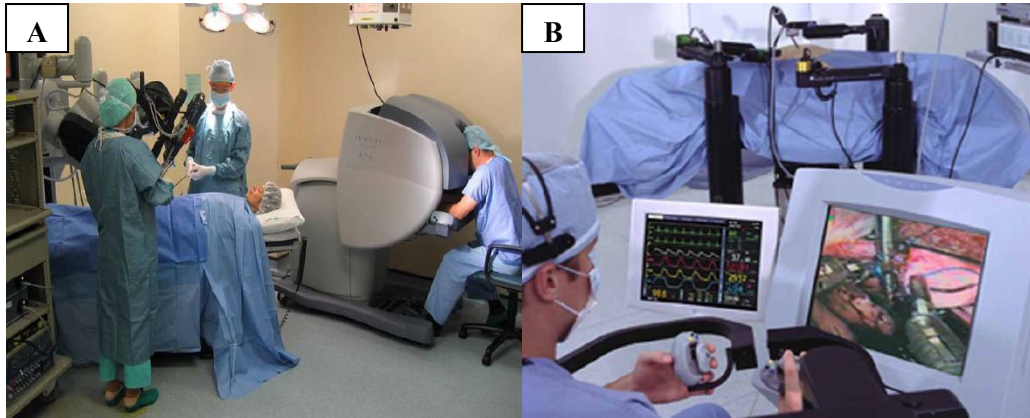


Figure 1.2: The Da Vinci (A) and Zues (B) surgical robots

Source: (A) www.davincisurgery.com and (B) www.allaboutroboticsurgery.com

The other types of health care robot that are widely used in medical field are the telemonitoring robots. Normally, a telemonitoring robot is controlled by a remote doctor for telerounding in hospitals which employs two ways audio visual communication with patients. This type of robots, for instance Remote Presence-7 (RP7) by Intouch Inc., were successfully used as telehealth system and become a new modality for doctor-patient interactions, particularly in areas where access to medical expertise is limited (Bartneck *et al.*, 2010). Figure 1.3 shows the RP7 robot during telerounding check on a patient in Shawnee Mission Medical Center, Kansas City.



Figure 1.3: Telerounding by a remote doctor using RP7 robot in Shawnee Mission Medical Centre, Kansas City

Source: www.intouchhealth.com/products/rp-7/

The development of surgical and telemonitoring robots in medical field is targeted to overcome human resource shortages and improve health care services. Moreover, robotic assistive limbs and rehabilitation robots are widely used to assist patients to lead a better life. For instance, robotic prosthetic devices aim to emulate the missing limb or other body part through replication of many joints and limb segments and seamless neural integration that provides intuitive control of the limb as well as touch feedback to the patient with missing limbs (Wang *et al.*, 2006). Robot assisted recovery and rehabilitation reduces recovery period of the patient and reduces trauma.

1.3 Research Motivation

The increase of road accidents is related to the rapid growth in population, economic development, industrialisation and motorisation encountered by the country (Nizam Mustafa, 2005). According to Abdul Rahman *et al.* (2005) injuries due to road traffic accidents are the third cause of admission and the fifth cause of death in Malaysian government hospitals in 2003, where traffic accidents in Malaysia have been increasing at the average rate of 9.7% per annum over the last three decades. Table 1.1 presents road accidents statistic from year 2003 to 2010, released by Road Safety Department, Ministry of Transportation (MOT).

Table 1.1: Road accidents statistics from year 2003 to 2010

Year		2003	2004	2005	2006	2007	2008	2009	2010
Total Accidents		298,653	326,814	328,268	341,232	363,319	373,047	397,330	414,421
Type of Injury	Death	6,286	6,228	6,188	6,287	6,282	6,527	6,745	6,872
	Critical	9,040	9,229	9,397	9,254	9,273	8,866	8,849	7,781
	Light	37,415	38,631	31,429	19,884	18,444	16,901	15,823	13,616

Source: Road Safety Department, Malaysian Ministry of Transportation

Studies also revealed that the number of fatalities (death within 30 days after accident) also increased due to serious injuries (Nizam Mustafa, 2005). Malaysia as a developing country, has introduced various campaigns, safety regulations and technological implementation to prevent road accidents rate. Measures taken to deliver efficient treatment and healthcare services to victims particularly in remote/