



**A VISUAL TRACKING RANGE OF MOTION
ASSESSMENT SYSTEM FOR LOWER LIMB JOINT**

by

**LIM CHEE CHIN
(1341310873)**

A thesis submitted in fulfilment of the requirements for the degree of
Doctor of Philosophy

**School of Mechatronic Engineering
UNIVERSITI MALAYSIA PERLIS**

2016

UNIVERSITI MALAYSIA PERLIS

DECLARATION OF THESIS

Author's full name : LIM CHEE CHIN
Date of birth : 15TH OCTOBER 1988
Title : A VISUAL TRACKING RANGE OF MOTION ASSESSMENT SYSTEM
FOR LOWER LIMB JOINT
Academic Session : 2016 / 2017

I hereby declare that the thesis becomes the property of Universiti Malaysia Perlis (UniMAP) and to be placed at the library of UniMAP. 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 is to be made immediately available as hard copy or on-line open access (full text)

I, the author, give permission to the UniMAP to reproduce this thesis in whole or in part for the purpose of research or academic exchange only. (except during a period of _____ years, if so requested above).

Certified by:

SIGNATURE

SIGNATURE OF SUPERVISOR

881015-10-5220

(NEW IC NO. / PASSPORT NO.)

DR.SHAFRIZA NISHA BIN BASAH

NAME OF SUPERVISOR

Date : _____

Date : _____

NOTES : * If the thesis is CONFIDENTIAL or RESTRICTED, please attach with the letter from the organization with period and reasons for confidentiality or restriction.

ACKNOWLEDGEMENT

All the praises and thanks to Buddha that I had fulfilled and complete my PhD research project smoothly without any difficulties.

Apart from the efforts of myself, the success of my graduate study depends largely on the encouragement and guidelines of many others. I would like to express my deepest appreciation to all who provided me the possibility to complete this dissertation.

First and foremost, I would like to take this opportunity to express my deep appreciation and gratitude to my supervisor Dr. Shafriza Nisha Basah, for his tremendous support and encouragement throughout my study.

In addition, I would like to extend my heartfelt appreciation to my co-supervisor of this research work, Dr. Marwan Affandi for his helpful suggestions, ideas and assistances that have deeply helped me in completing this research. He is a very good mentor in conveying a spirit of adventure to research convincingly. Apart from that, I would like to thank my former co-supervisor Prof. Dr. Sazali Yaacob for his kindness, guidance, constant motivation and encouragement to make this journey.

Furthermore, I would like to express my sincere thanks to the Head of Orthopaedics Department from Hospital Tunku Fauziah, Mr. Mohammad Yazid Bin Din, for his professional advice and knowledge in this research. In addition, I want to thank all the medical doctors and co-operation partners from Orthopaedics Department of Hospital Tuanku Fauziah, Perlis for their opinions and experiences in helping me during clinical experiment. In addition, I would like to thank Orthopaedics Surgeon, Mr. Yeap Ewe Juan, for sharing his medical knowledge in human anatomy, joint illness and clinical research application. I would like to thank to Malaysian Ministry of Health (MOH) for the approval for medical research and ethnics of this project.

I would like to express my appreciation to University Malaysia Perlis (UniMAP), for permission to conduct this research in my study. I want to thank the Dean of Centre of Graduate Studies Professor Dr. Mohd, Yusoff Mansor for his support and approval of my study in UniMAP. I also want to thank Research Acculturation Grant Scheme (RAGS) from the Malaysian Ministry of Higher Education (MoHE) for funding this research. In addition, I want to extend my boundless appreciation and gratitude to the Dean of School Mechatronic Engineering, Professor Dr. Abu Hassan Abdullah for his support and approval of my study under the sponsorship of SLAI scholarship.

I would like to thank to the Dean of School Manufacturing Engineering, Assoc. Prof. Dr. Khairul Azwan Ismail for his support and approval to borrow me the medical equipment. Moreover, I would like to thank to lab assistant, Mr. Mazlan for helping in understanding the electrogoniometer.

Special thanks to all my friends and members from Intelligent Signal Processing Research Cluster who have directly and indirectly gave me a helping hand. Their kind-heartedness is much appreciated and welcomed. I enjoyed every moment we have shared together and I appreciated everything that I have gained from it.

Most importantly, I would like to dedicate my truthful thankfulness to my dearest parents, Mr. Lim See Guan and Mdm. Foong Chai Peng, for their unconditional love and patience in raising me up to more than I can be. Thank to my siblings for their moral support as well as their continuous motivation. Last but not least, special thanks to Mr. Chong Yen Fook who acted as my pillar and supports me all the way in my study, without them this research would never reached to this stage.

Finally, I also place in record, my sense of gratitude to one and all who, directly and indirectly, have lent their hands in my study.

Lim Chee Chin

TABLE OF CONTENTS

	PAGE
DECLARATON OF THESIS	i
ACKNOWLEDGEMENT	ii
TABLE OF CONTENTS	iv
LIST OF TABLES	x
LIST OF FIGURES	xiii
LIST OF ABBREVIATION	xix
ABSTRAK	xxii
ABSTRACT	xxiv
CHAPTER 1: INTRODUCTION	
1.1 Introduction	1
1.2 Background and Motivation	1
1.3 Problem Statement	4
1.4 Research Objectives	6
1.5 Thesis Organization	7
CHAPTER 2: LITERATURE REVIEW	
2.1 Introduction	9
2.2 Lower Limb Joint	9
2.2.1 Lower Limb Injuries	11
2.2.2 Risk Factors	15

2.2.3 Diagnosing Lower Limb Joint Injuries and Disorder	16
2.2.4 Treatment of Lower Limb Joint Injuries	17
2.2.5 Range of Motion for Lower Limb Joint Flexion	17
2.3 Range of Motion Measurement System	23
2.3.1 Universal Goniometer	25
2.3.2 Electrogoniometer	26
2.3.3 Human Motion Capture	28
2.3.3.1 Marker-Based System	28
2.3.3.2 Marker-less System	30
2.4 Summary	32
CHAPTER 3: RESEARCH METHODOLOGY	
3.1 Introduction	34
3.2 Design and Development of System	38
3.3 Experimental and Validation of System	39
3.4 Clinical Test	40
3.5 Clinical Study Cases: Total Knee Replacement Recovery Process	41
3.6 Summary	42
CHAPTER 4: DESIGN DEVELOPMENT OF LOWER LIMB JOINT RANGE OF MOTION ASSESSMENT SYSTEM	
4.1 Introduction	43
4.2 Need Identification	45
4.2.1 Problem Statement and System Need	47
4.2.2 Survey Design and Analysis	48

4.2.3 Survey Analysis of Problem Statement	49
4.2.4 Survey Analysis of System Need	53
4.2.5 Need Organization and Establish importance	54
4.3 Conceptual Design	57
4.3.1 Concept Generation	57
4.3.2 Selection of Conceptual Options	59
4.4 Embodiment Design of System	63
4.4.1 Initialization Graphical User Interface (GUI) of System	65
4.4.2 Pre-processing and Motion Tracking	67
4.4.2.1 Colour Panel Selection	69
4.4.2.2 Image Subtraction	71
4.4.2.3 Image filtering using Median Filter	73
4.4.2.4 Binary Image Thresholding	75
4.4.2.5 Noise Removal and Extraction	79
4.4.2.6 Image Blob Analysis	81
4.4.3 Lower Limb Joint Evaluation Techniques	83
4.5 Summary	88
 CHAPTER 5: EXPERIMENTAL AND VALIDATION OF SYSTEM	
5.1 Introduction	90
5.2 Data Acquisition: Landmark Setup and System Setup	91
5.3 Experimental Procedures	94
5.4 Statistical Analysis for Data Validity	99
5.5 Result and Discussion of Experimental and Validation	100
5.5.1 Influence of Light Intensity	100

5.5.2 Influence of Distance between the camera and subject	103
5.5.3 Influence of Camera Elevation	105
5.5.4 Sensitivity Test	107
5.6 Summary	107
CHAPTER 6: CLINICAL TEST	109
6.1 Introduction	109
6.2 Data Acquisition: Bony Landmark Setup	112
6.2.1 Ankle Dorsiflexion and Plantarflexion	112
6.2.2 Knee Flexion	114
6.2.3 Hip Flexion	116
6.3 Data Acquisition: System Setup	117
6.3.1 Universal Goniometer: Data Acquisition Setup & Examination Procedures	117
6.3.2 Electrogoniometer: Data Acquisition Setup & Examination Procedures	123
6.3.3 Visual Tracking System: System Setup & Examination Procedures	129
6.4 Experimental Procedures of Clinical Test	131
6.5 Sample Determination	133
6.5.1 General Inclusion and Exclusion Criteria	134
6.5.2 Ethics Statement	137
6.6 Statistical Analysis for ROM Measurement Data Analysis	137
6.6.1 Statistical Decision Method	140
6.7 Result and Discussion of Clinical Test	142
6.7.1 Result of Healthy Control Test	143
6.7.1.1 Ankle Joint ROM Analysis	144

6.7.1.2 Knee Joint ROM Analysis	157
6.7.1.3 Hip Joint ROM Analysis	163
6.7.1.4 Inaccurate Measurement of using Electrogoniometer	168
6.7.1.5 Summary of Healthy Control Test Normal	172
6.7.2 Result of Injured Subject Test	175
6.7.2.1 Ankle Joint ROM Analysis	176
6.7.2.2 Knee Joint ROM Analysis	183
6.7.2.3 Hip Joint ROM Analysis	189
6.7.2.4 Summary of Injured Subject Test	195
6.8 Summary	199

CHAPTER 7: CLINICAL CASE STUDY: TOTAL KNEE REPLACEMENT RECOVERY PROCESS

7.1 Introduction	201
7.2 Total Knee Replacement Recovery and Rehabilitation Process	203
7.3 Sample Study Determination	205
7.4 Clinical Case Study Procedures	207
7.5 Result and Discussion for TKR Clinical Cases	210
7.5.1 TKR Improvement Classes	211
7.5.2 Timeline-based TKR Recovery Process	213
7.5.3 Comparison of TKR Recovery Process among Three Measurement Systems	215
7.6 User Feedback of Visual Tracking ROM Assessment System	217
7.7 Summary	222

CHAPTER 8: CONCLUSION

8.1 Introduction	224
8.2 Conclusion	224
8.3 Research Contributions	227
8.4 Future work	229
REFERENCES	230
APPENDIX A	239
APPENDIX B	246
APPENDIX C	259
APPENDIX D	270
APPENDIX E	274
APPENDIX F	283
LIST OF PUBLICATIONS	287
LIST OF AWARDS	288

©This item is protected by original copyright

LIST OF TABLES

NO.		PAGE
1.1	Percentage for each type of injury for various falling from a height types (WorkSafe British Columbia, 2013)	3
2.1	Ankle motion impairment estimates (American Medical Association, 2002)	19
2.2	Knee motion impairment estimates (American Medical Association, 2002)	21
2.3	Hip motion impairment estimates (American Medical Association, 2002)	22
2.4	Comparison of various goniometers commonly used to measure joint ROM (Bronzino, 2000)	24
4.1	Typical survey question, data types and analysis potential (Great Brook Consulting, 2000)	49
4.2	Survey analysis of problems faced by medical doctors when diagnosing joint injuries patients	50
4.3	Survey analysis on the important features for evaluating a medical measurement system.	54
4.4	Generated conceptual options, datum device and available market products.	61
4.5	Pugh's method to select lower limb joint ROM assessment system	62
4.6	Visual tracking ROM assessment system specification	64
5.1	Parameters of the validation experiment	96
5.2	Comparison between UGM, EGM and VTS for mean percentage error for varying light intensity level	103
5.3	Result of sensitivity test	107
6.1	Sample size of clinical test study subjects	135
6.2	Injured subjects sample size of subgroups division	136
6.3	Statistical description of ankle plantarflexion	145
6.4	Significant difference analysis of combination of left and right normal ankle plantarflexion using three measurement systems	148
6.5	Comparison of significant difference between each other of measurement	149

	system when right and left joint is combined for ankle plantarflexion.	
6.6	Comparison of significant difference between each other of measurement system when right and left ankle plantarflexion joint is separated.	151
6.7	Statistical description of ankle dorsiflexion	152
6.8	Significant difference analysis of combination of left and right normal ankle joint dorsiflexion using three measurement systems	155
6.9	Comparison of significant difference between each other of measurement system when right and left ankle joint dorsiflexion is combined	156
6.10	Comparison of significant difference between each other of measurement system when right and left ankle joint dorsiflexion is separated	157
6.11	Statistical description of knee flexion	158
6.12	Significant difference analysis of combination of left and right normal knee flexion using three measurement systems	160
6.13	Comparison of significant difference between each other of measurement system when right and left ankle joint dorsiflexion is combined	162
6.14	Comparison of significant difference between each other of measurement system when right and left knee flexion is separated.	163
6.15	Statistical description of hip flexion	164
6.16	Significant difference analysis of combination of left and right normal hip flexion using three measurement systems	166
6.17	Comparison of significant difference between each other of measurement system when right and left hip flexion is combined	167
6.18	Comparison of significant difference between each other of measurement systems when right and left hip flexion is separated	168
6.19	The inaccurate data taken by the electrogoniometer sensor for right hip	170
6.20	Significant difference for the inaccurate measurement using electrogoniometer for right hip	170
6.21	Comparison analysis between three measurement systems	172
6.22	Significant difference between left and right limb joint motion	173
6.23	Significant difference between three measurement systems for limb joint motion	174

6.24	Comparison between the three measurement systems for joint motion without combining left and right limbs data for analysis	175
6.25	Relative difference standard deviation (RDSD) for the comparison between injured and normal joint motion using three measurement systems (VTS, EGM & UGM)	196
6.26	Coefficient Variation (CV) for the comparison between injured and normal joint motion using three measurement systems (VTS, EGM & UGM)	198
7.1	The general inclusion and exclusion criteria of selected total knee replacement patients to be subject.	207

©This item is protected by original copyright

LIST OF FIGURES

NO.		PAGE
2.1	Bones and joints for the lower limb (Campbell, 2015)	9
2.2	Posterior view of knee (Tiobiofemoral) joint (Behnke, 2012)	10
2.3	Hip joint structure: posterior view and anterior view	11
2.4	Ankle plantarflexion and dorsiflexion (Livingstone, 2008)	19
2.5	Knee motion (Medwick, 2016)	20
2.6	Hip motion (Neumann, 2009)	21
2.7	Universal goniometer (UGM)	25
2.8	Strain gauge based Electrogoniometer (EGM): Definitions of the movements measured by each strain gauge transducer in the electrogoniometer. (a) Top View: One transducer measures right deviations (RD) and left deviations (LD), (b) Side View: other transducer measures flexion (FLEX) and extension (EXT)	26
2.9	Qualisys Track Manager (QTM) and its reflective markers (Franco, 2013)	30
3.1	Research methodology and scope of work of ROM assessment system for human lower limb joint	37
4.1	Design and development process of lower limb joint ROM assessment system	45
4.2	Flowchart of problem statements and need identification of the lower limb of ROM assessment system	46
4.3	Device usages for ROM measurement: (a) Qualisys Track Manager, (b) Estimation, (c) Electrogoniometer, and (d) Universal Goniometer.	51
4.4	Frequent rate of medical doctors to use universal goniometer	52
4.5	Difficulties of using universal goniometer	53
4.6	Specification needs of lower limb joint ROM assessment system	55
4.7	Importance functioning aspect to generate conceptual options	58
4.8	Embodiment design of the visual tracking system algorithm	65

4.9	MATLAB GUIDE Workspace to create system graphical user interface (GUI)	66
4.10	GUI of lower limb joint ROM assessment system	67
4.11	Pre-processing and motion tracking algorithm flowchart	68
4.12	Original raw RGB image captured from camera	69
4.13	The domain of variation of the Red, Blue, Green components can be represented in 3 dimensions by what is called a “Colour Cube”. Its “skeleton” allows showing in particular the “path” of the grayscale. (Paris, 2002)	70
4.14	Grayscale intensity before colour selection (a) Grayscale raw image and (b) Histograms of grayscale image	70
4.15	Grayscale image with colour selection before image subtraction, example green colour selection: (a) Grayscale image green colour selection (b) Histogram of grayscale green colour selection	71
4.16	Image subtraction before image filtering: (a) Grayscale subtraction image (b) Histograms for image subtraction	73
4.17	3x3 neighbourhood kernel median filter	74
4.18	Median filtered before image thresholding (a) Median filtered image (b) Histograms for median filtered image	75
4.19	Image histogram of automatically thresholding value selection	76
4.20	Binary image thresholding before noise removal : (a) Binary image after thresholding and (b) Histograms after thresholding	79
4.21	8-connected neighbours and connected component labelling techniques	80
4.22	Noise Removal before blob analysis: (a) Binary image of noise removal (b) Histogram of noise removal	81
4.23	Display of blob analysis using Bounding Box and Centroid features	82
4.24	Three points detached and trigonometry theory applied	83
4.25	Flowchart of lower limb joint evaluation.	84
4.26	Angular motion of left ankle joint (a) Initial: Ankle starting position (b) Ankle Dorsiflexion (c) Ankle Plantarflexion	85

4.27	Angular motion of left knee joint: (a) Initial: Knee starting position (b) Knee flexion	86
4.28	Angular motion of left hip joint (a) Initial: Hip starting position (b) Hip flexion	87
5.1	Point landmark for acquisition setup of validation and testing experiment (Camera distance test, Light intensity test and Camera elevation test)	92
5.2	Point landmark for acquisition setup of sensitivity test in experiment	93
5.3	Visual tracking camera system setup for data acquisition	94
5.4	Flowchart of validation and testing experiment procedure	98
5.5	Percentage error at light intensity of 100 Lux	101
5.6	Percentage error at light intensity of 150 Lux	102
5.7	Percentage error at light intensity of 200 Lux	102
5.8	Percentage error of visual tracking system performance varying actual distance between the subject and camera	104
5.9	Comparison of mean percentage error between VTS, UGM and EGM	105
5.10	Percentage error in ROM when camera elevation	106
5.11	Mean percentage error in ROM when camera elevation	106
6.1	Starting position for measurement of ankle joint flexion (Angles are measured from neutral (plantargrade), which is measured as 0°); and Bony landmarks on ankle joint that help to orientate the device for measurement. (Reese et al., 2009)	113
6.2	Range of motion: (a) ankle dorsiflexion (normal range is typically 0° - 20°); (b) ankle plantarflexion (normal range is typically 0° - 50°)	114
6.3	Starting position for measurement of knee flexion (angles are measured as neutral, which is measured as 0°); Bony landmarks for measurement device alignment of knee joint (Reese et al., 2009)	115
6.4	Range of knee flexion (normal range is typically 0° - 135°)	115
6.5	Starting position for measurement of hip flexion (Angles are measured from hip neutral, which is taken as 0°)	116
6.6	Bony landmarks for measurement device alignment of hip joint that help to orientate the device for measurement; and Range of hip flexion (normal range is typically 0° - 125°)	116

6.7	Start position: positioning and alignment of the universal goniometer on ankle joint.	118
6.8	End position demonstrate proper alignment of universal goniometer: (a) Dorsiflexion: Pull foot towards them; (b) Plantarflexion: Point foot away	119
6.9	Start position for measurement of knee flexion demonstrating proper initial alignment of the universal goniometer	120
6.10	End position of knee flexion demonstrate proper alignment of universal goniometer	121
6.11	Start position: positioning and alignment of the universal goniometer on hip joint.	121
6.12	End position of hip flexion demonstrate proper alignment of goniometer	122
6.13	Electrogoniometer (Twin axis goniometer “SG”) and its mechanical properties limitation (Biometrics, 2002)	124
6.14	Placement of Electrogoniometer sensor on foot for ankle joint measurement	125
6.15	Electrogoniometer reading during (a) Ankle dorsiflexion (b) Ankle plantarflexion	125
6.16	Placement of electrogoniometer for knee joint: (a) Theoretically (b) During clinical test for knee flexion: end position (c) During clinical test for knee flexion: start position	126
6.17	Electrogoniometer reading during (a) Left knee flexion (b) Right knee flexion	127
6.18	Placement of electrogoniometer sensor on hip joint: (a) Theoretically (b) Clinical test for hip flexion start position (c) Clinical test for hip flexion end position	128
6.19	Electrogoniometer reading during (a) Left hip flexion (b) Right hip flexion	128
6.20	Visual tracking system setup and data acquisition setup (a) Knee joint (b) Hip joint, and (c) Ankle joint	130
6.21	Graphical User Interface (GUI) for visual tracking system	130
6.22	Flowchart of clinical experimental procedure	132
6.23	Student’s <i>t</i> -distributions for various values, <i>v</i> . (Spiegel & Stephens, 1999)	139
6.24	Over-compression during ankle plantarflexion posterior view	169

6.25	Electrogoniometer effect from over-stretching and dirt (Dry epidermis and dust)	170
6.26	Comparison of mean and standard deviation between mild injuries and normal during ankle plantarflexion	178
6.27	Relative difference of mean and standard deviation between mild injury and normal during ankle plantarflexion	178
6.28	Comparison of mean and standard deviation between moderate injuries and normal of ankle plantarflexion	180
6.29	Relative difference of mean and standard deviation between moderate injury and normal during ankle plantarflexion	180
6.30	Comparison of mean and standard deviation between severe injuries and normal during ankle plantarflexion	182
6.31	Relative difference of mean and standard deviation between severe injury and normal of ankle plantarflexion	182
6.32	Comparison of mean and standard deviation between mild injuries and normal of knee flexion	184
6.33	Relative difference of mean and standard deviation between mild injury and normal of knee flexion	185
6.34	Comparison of mean and standard deviation between moderate injury and normal of knee flexion	186
6.35	Relative difference of mean and standard deviation between moderate injury and normal of knee flexion	187
6.36	Comparison of mean and standard deviation between severe injuries and normal of knee flexion	188
6.37	Relative difference of mean and standard deviation between severe injuries and normal of knee flexion	189
6.38	Comparison of mean and standard deviation between mild injuries and normal of hip flexion	191
6.39	Relative difference of mean and standard deviation between mild injuries and normal of hip flexion	191
6.40	Comparison of mean and standard deviation between moderate injuries and normal of hip flexion	193
6.41	Relative difference of mean and standard deviation between moderate injuries and normal of hip flexion	193

6.42	Comparison of mean and standard deviation between severe injuries and normal of hip joint during hip flexion	195
6.43	Relative differences of mean and standard deviation between severe injuries and normal of hip flexion	195
7.1	Type of Knee OA : (a) Drawing depicting a normal knee alignment, varus (bowed legs) and valgus (knock knee) alignment; (b) A standing AP view of both knees showing normal alignment on the right and varus on the left; (c) Severe arthritis in the lateral compartment causing valgus deformation of the knee (Cameron, 2013)	206
7.2	Flowchart of the data collection procedures for clinical case study	208
7.3	Timeline of monitoring the ROM of TKR patients	209
7.4	ROM recovery measurement of the knee flexion from TKR patients by using visual tracking system	211
7.5	Comparison of visual tracking system with universal goniometer and electrogoniometer for Total Knee Replacement recovery process for each patient respectively: (a) TKRP1 (b) TKRP2 (c) TKRP3 (d) TKRP4 (e) TKRP5	216
7.6	Evaluation of doctor on the visual tracking system in term of user-friendly	218
7.7	Evaluation of doctor on the visual tracking system in term of efficiency	219
7.8	Evaluation of doctor on the visual tracking system in term of validity	220
7.9	Reasonable price of the visual tracking system	221
7.10	Visual tracking system evaluation	222

LIST OF ABBREVIATION

ACL	Anterior Cruciate Ligament of knee joint
Ave	Average
BMI	Body Mass Index
cm	Centimetre
CDC	Centres for Disease Control and Prevention
CL	Confidence Limit
CV	Coefficient of Variation
DOF	Degree of Freedom
EGM	Electrogoniometer
EXT	Extension
FLEX	Flexion
GUI	Graphical User Interface
LD	Left Deviation
MBS	Marker-based System/ Solution
MCL	Medial Collateral Ligament of knee joint
<i>Mild_EGM</i>	Mild injury measured by Electrogoniometer

<i>Mild_VTS</i>	Mild injury measured by Visual Tracking System
<i>Mild_UGM</i>	Mild injury measured by Universal Goniometer
MLS	Marker-less System/Solution
Mo	Moderate
<i>Mo_EGM</i>	Moderate injury joint flexion measured by Electrogoniometer
<i>Mo_VTS</i>	Moderate injury joint flexion measured by Visual Tracking System
<i>Mo_UGM</i>	Moderate injury joint flexion measured by Universal Goniometer
MPE	Mean Percentage Error
MRI	Magnetic Resonance Imaging
N	Normal
<i>N_EGM</i>	Normal joint flexion measured by Electrogoniometer
<i>N_VTS</i>	Normal joint flexion measured by Visual Tracking System
<i>N_UGM</i>	Normal joint flexion measured by Universal Goniometer
NTDB-NSP	National Trauma Data Bank – National Sample Program
OA	Osteoarthritis
Pat ID	Patient Identification
PE	Percentage Error

QTM	Qualisys Manager Track System
ROM	Range of Motion
RD	Right Deviation
RDM	Relative Difference of Mean
RDS	Relative Difference of Standard Deviation
TKR	Total Knee Replacement
TL	Transverse Ligament of knee joint
SD	Standard Deviation
SE	Standard Error
Sev	Severe
<i>Sev_EGM</i>	Severe injury joint flexion measured by Electrogoniometer
<i>Sev_VTS</i>	Severe injury joint flexion measured by Visual Tracking System
<i>Sev_UGM</i>	Severe injury joint flexion measured by Universal Goniometer
UGM	Universal Goniometer
vs.	versus
VTS	Visual Tracking ROM Assessment System / Visual Tracking System

Sistem Penilaian Pengesanan Penglihatan Pelbagai Gerakan Sendi Tungkai Bawah

ABSTRAK

Ketepatan ukuran pelbagai gerakan (ROM) pada sendi tungkai bawah adalah penting untuk diagnosis tahap keterukan kecederaan sendi tungkai bawah. Ia adalah penting untuk membantu doktor perubatan dan ahli fisioterapi untuk menentukan rawatan dan latihan pemulihan yang diperlukan oleh pesakit kecederaan sendi tungkai bawah secara khususnya. Sistem pengukuran perubatan yang semasa seperti Universal Goniometer (UGM) mempunyai peleraian yang sebesar 1° menyebabkan ralat pemerhatian; manakala Electrogoniometer (EGM) terdedah kepada kedudukan sensor yang tidak tepat dan terlepas apabila bergerak kerana kekurangan sifat-sifat mekanikal. Oleh itu, Sistem penilaian pengesanan penglihatan ROM (VTS) bagi sendi tungkai bawah ukuran dicadangkan. Tujuan penyiasatan ini adalah untuk membangunkan satu kaedah untuk mengukur ROM sendi tungkai bawah dan memeriksa ROM yang diperolehi antara VTS dengan EGM dan UGM untuk mengukur sudut sendi tungkai bawah. Terdapat tiga eksperimen utama yang telah dijalankan iaitu, Experiment Pengesanan, Ujian Klinikal dan Kajian Kes Klinikal. Eksperimen pengesanan dilakukan pada sistem pengesanan penglihatan yang dibangunkan sebelum digunakan pada subjek manusia yang sebenar untuk memastikan prestasi sistem dan keselamatannya. Sistem ini telah diuji di bawah perubahan keamatan cahaya, jarak kamera, sudut ketinggian kamera dan lokasi penanda untuk menentukan keadaan operasi yang optimum. Dalam ujian klinikal, terdapat dua ujian yang akan dijalankan iaitu Ujian Kawalan Sihat dan Ujian Subjek Cedera. Penemuan seramai 20 subjek kawalan sihat telah membuktikan bahawa sendi tungkai bawah kiri dan kanan manusia adalah serupa (keserupaan 99.80% ~ 97.64%) bagi subjek yang sihat. Perbandingan antara VTS, EGM dan UGM mendapati bahawa ketepatan bagi setiap dua sistem yang dibandingkan dengan yang lain adalah sangat berbeza bagi VTS vs. EGM dan EGM vs. UGM. VTS vs. UGM menghasilkan ketepatan tertinggi bagi semua pergerakan sendi dibandingkan dengan VTS vs. EGM dan EGM vs. UGM; ketepatan itu adalah 99.46% untuk perlenturan lutut kiri. Di samping itu, sejumlah 70 orang subjek yang cedera (termasuk sendi buku lali, sendi lutut dan sendi pinggul) telah menjalani ujian subjek cedera untuk membandingkan tahap keterukan antara penyakit dan ketiga-tiga sistem pengukuran. Dalam ujian subjek yang cedera, VTS memberikan pekali perubahan (CV) dibandingkan dengan EGM dan UGM untuk pelenturan lutut bagi kecederaan sederhana adalah 2.45%. Oleh itu, VTS berupaya untuk memberikan pengukuran ROM yang paling tepat. Perbezaan relatif untuk sisihan piawai (RDSD) yang terkecil yang diberikan oleh VTS vs. EGM semasa kecederaan parah pelenturan pinggul adalah 1.05%. VTS vs. UGM memberikan RDSD yang paling kecil disbanding dengan VTS vs. EGM dan VTS vs. UGM ringan vs. normal (semua pelenturan), sederhana vs normal (untuk pelenturan lutut dan pelenturan pinggul) dan parah vs. normal (perlenturan lutut). Penggunaan VTS untuk kajian kes klinikal ditunjukkan untuk memantau ROM semasa pemulihan Pengantian lutut palsu keseluruhan (TKR) dan penormalan kembali proses daripada 5 orang pesakit perempuan. Hasil kajian kes klinikal menunjukkan bahawa VTS menyediakan pengukuran ROM lebih tepat dengan serakan yang kecil dibandingkan dengan kedua-dua UGM dan EGM. Tambahan pula, VTS umpan balik dikumpulkan daripada 20 orang doktor perubatan. Umpan balik Ini menunjukkan bahawa VTS boleh digunakan untuk menggantikan UGM atau EGM dalam penilaian ROM. Kesimpulannya, sistem

pengesanan penglihatan penilaian ROM adalah sistem pengukuran yang paling sesuai digunakan dalam menilai ukuran ROM pesakit untuk mengenal pasti aras keterukan sendi tungkai bawah.

©This item is protected by original copyright