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**

881015-10-5220 **(NEW IC NO. / PASSPORT NO.)**

Date :_____

_____ **SIGNATURE OF SUPERVISOR**

DR.SHAFRIZA NISHA BIN BASAH **NAME OF SUPERVISOR**

Date : _____

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

LIST OF TABLES

LIST OF FIGURES

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
Mild_EGM	Mild injury measured by Electrogoniometer

Mild_VTS	Mild injury measured by Visual Tracking System
Mild_UGM	Mild injury measured by Universal Goniometer
MLS	Marker-less System/Solution
Mo	Moderate
Mo_EGM	Moderate injury joint flexion measured by Electrogoniometer
Mo_VTS	Moderate injury joint flexion measured by Visual Tracking System
Mo_UGM	Moderate injury joint flexion measured by Universal Goniometer
MPE	Mean Percentage Error
MRI	Magnetic Resonance Imaging
N	Normal
N_EGM	Normal joint flexion measured by Electrogoniometer
N_VTS	Normal joint flexion measured by Visual Tracking System
N_UGM	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
RDSD	Relative Difference of Standard Deviation
TKR	Total Knee Replacement
TL	Transverse Ligament of knee joint
SD	Standard Deviation
SE	Standard Error
Sev	Severe
Sev_EGM	Severe injury joint flexion measured by Electrogoniometer
Sev_VTS	Severe injury joint flexion measured by Visual Tracking System
Sev_UGM	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 Pengesahan, Ujian Klinikal dan Kajian Kes Klinikal. Eksperimen pengesahan 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.