DEVELOPMENT OF GRIPPING ASSISTIVE DEVICE FOR TRAINING

BY

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ABSTRACT

Gripping is an everyday task which goes unnoticeable. Since it is an essential daily movement, without this motion, a lot of activities involving this movement could not be done. However, due to the growing process or some injury, the grasping movement become disrupted, which cause difficulties to do some daily activities. These impacts depend on individual and also in different ways regardless of age and how the body drastically become weak and fragile, less adaptable and less impervious to sickness and damage. Patients affected with hand gripping issues typically require long term care. This also contributes towards their ability to recover much longer as their regular activity reduces and dependency on other increases. Therapy, as an early rehabilitation within the golden period (less than 3 three months prior to incident), is required to improve the gripping motion and regain back the strength of the affected joints as well as muscles. Rehabilitation also helps to improve the patient's ability to return the patient to the level of premorbid function. The current situation is that the rehabilitation process takes longer as there are few physiotherapists available in hospitals. It is anticipated that a mechatronics approach using robotics-based devices have been seen as a promising candidate to assist existing forms of the rehabilitation process. The idea is to develop a basic function rehabilitation robot to support the physiotherapist. The rehabilitation robot is designed to help with the gripping process, where the system is based on a master-slave mechanism which needs a healthy hand to control the weak hand. The system uses a leap motion sensor as an input, and the output is an exoskeleton. A gyroscope was used to indicate the finger position and placed on top of the exoskeleton. The exoskeleton has been tested by a subject for several times. The results shows the simulation of exoskeleton that can do flexion and extension process. The errors between the desired extension angle value and the extension angles on link 1 and link 2 are 5.58% and 11.02% respectively. However, this design need some improvement on the material and angle sensors selection. The material must be light and smooth surface and the angle sensor must be high in precision and accuracy.

خلاصة البحث

إن إمساك أي شيء مهمة يومية التي غير ملحوظة. ولا يمكن القيام بالكثير من الأنشطة التي تنطوي عنها بدون هذه الحركة لأنها حركة يومية أساسية. ولكن بسبب العمليات المتنامية أو بعض الإصابات، قد تتعطل حركة إمساك الشيء مما يسبب صعوبات في القيام ببعض الأنشطة اليومية. وتعتمد هذه التأثيرات على الأفراد والأساليب بغض النظر على العمر وكذلك ضعف حركة الجسم، أقل تكيفا وقدرة في حالة المرض والأضرار. كهذا، إن المرضى الذين يعانون من مشاكل في الإمساك باليد يحتاجون إلى العلاج لمدة طويلة. وهذا يساهم في تعزيز قدرتهم على التعافي لأطول فترة مع الانخفاض نشاطهم المنتظم وزيادة الاعتماد على الآخرين. والعلاج هو إعادة التأهيل في فترة مبكرة (أقل من ثلاثة أشهر من وقوع الحادث)، والمطلوب على التحسين حركة الإمساك واستعاد إلى قوة المفصل المتضررة وكذلك بالعضلات. إن التأهيل يساعد على تحسين قدرة المريض وإعادته إلى المستوى السابق. والحالة الراهنة هي أن عملية إعادة التأهيل تستغرق وقتا أطول لأن هناك قليل من الفيزيائيين المتاحين في المستشفيات. ومن المتوقع أن الميكاترونيكس باستخدام الأجهزة التي تستند إلى الإنسان الألى اعتبر مرشحة لاعدة للمساعدة الأشكال القائمة لعملية إعادة التأهيل. وتتلخص الفكرة في تطوير روبوت الأساسي للوظائف إعادة تأهيل دعما للمعالجين الفيزيائيين. لقد تم تصمم روبوت لإعادة التأهيل ومساعدة عملية الإمساك، حيث يستند النظام على الآلية الرئيسية التي تحتاج إلى اليد الصراحة للسيطرة على اليد المتضرة. ويستخدم النظام المستشعر الحركة كالإدخال، والهيكل الخارجي كالإنتاج. وتم استخدام الجيروسكوب للإشارة إلى موضع الإصبع و توضع فوق الهيكل الخارجي. وقد تم اختبار الهيكل من قبل المشارك_لعدة مرات. لوضع النتائج محاكاة الهيكل الخارجي الذي يمكن أن يقوم به المرونة وعملية التمديد. الأخطاء بين قيمة الزاوية الامتداد المطلوبة وزواية الامتداد في لارتباط 1 والارتباط 2 ونسبتهما 5.58% و11.02% على التوالي.ومع ذلك، يحتاج هذا التصميم إلى بعض التحسينات في تحديد المواد ومستشعرات الزوايا. يجب أن تكون المادة سطحًا خفيفًا وناعمًا. ويجب أن يكون مستشعر الزاوية عالي الدقة والدقة.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Science (Mechatronics Engineering).

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…………………………………..
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DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

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LIST OF SYMBOLS

V	Voltage
v	Speed
Ʈ	Torque
ρ	Density
E	Young’s Modulus
θ	Degree
F	Force
σ	Stress
ε	Elastic Strain
τ	Shear Stress
SF	Safety Factor

LIST OF ABBREVIATIONS

MMA	Malaysian Medical Association
CAM	Complementary and Alternative Medicine
NCCAM	National Centre for Complementary and Alternative Medicine
HOWARD	Hand-Wrist Assisting Robotic Device
PP	Proximal Phalange
MP	Middle Phalange
DP	Distal Phalange
MCP	Metacarpo Phalange
PIP	Proximal Interphalange
DIP	Distal Interphalange
EMG	Electromyography
API	Application Programming Interface
USB	Universal Serial Bus
LED	Light Emitting Diode
IR	Infrared
IMU	Inertial Measurement Unit
PWM	Pulse Width Modulation
ADC	Analog Digital Converter
PLA	Polyactide
DOF	Degree of Freedom

COM	Communication

CHAPTER ONE

INTRODUCTION

1.1 INTRODUCTION

Those aged 60 years and above are defined as elderly, as recommended by the Malaysian Medical Association (MMA). According to the Department of Statistics Malaysia (Census 2000), the Malaysian elderly population of 60 and above is increasing progressively and is predicted to increase to 3.2 million people by the year 2020. Although this indicates an increase in life expectancy, from healthcare perspective, this reflects that the population will be susceptible to different diseases and morbidities and, therefore, poses a higher demand for all medical and healthcare services. To be precise, Complementary and Alternative Medicine (CAM) found to be used often by the elderly, other than other ages, to improve their health (Mitha et al., 2013).

According to National Centre for Complementary and Alternative Medicine (NCCAM), complementary and alternative medicine (CAM) is defined as a group of diverse medical and healthcare systems, practices, and products that are not generally considered part of conventional medicine. In Malaysia, CAM includes practices such as traditional Malay medicine, Islamic medical practice, traditional Chinese medicine, traditional Indian medicine, homeopathy, and complementary therapies, and excludes medical or dental practices utilized by registered medical or dental practitioners. In one Malaysian study it was reported that 69.4% of the Malaysian population used traditional and complementary medicines in their whole lifetime. The ageing process is natural and affects everyone in different ways. The body naturally becomes weaker, less flexible and less resistant to illness and injury. There are a large number of disabilities that are common in the elderly such as Parkinson's disease and reduced mobility. Physiotherapy is very important in treating these disabilities by reducing symptoms, adapting function and maintaining quality of life. The health care system in Malaysia is primarily geared towards short term care and hospitalisation. The elderly with their chronic diseases and problems require long term care. Rehabilitation from acute illness often lacks in our hospitals in order to help return the elderly patient to the level of premorbid function.

Rehabilitation is a process by which patients undergo treatment to help them return to healthy life by regaining and relearning the skills of everyday living (Maciejasz, Eschweiler, Gerlach-Hahn, Jansen-Troy, & Leonhardt, 2014). Elderly rehabilitation is maintaining and improving the general health and ability of elderly individuals. It also focuses on facilitating the patient to understand and comply challenges, prevent subsequent problems and instruct family members to participate in a supporting part.

The practice of robotic mechanisms for rehabilitation training is a comparatively recent area within the field of robotics in healthcare and emerged from the concept of adopting robots to assist people with impairments. In return, this has led to the development of various rehabilitation robotic devices. Considering the robot as a new development exercise-tool under the therapist’s guidance, the key challenge in the area of rehabilitation robotics is how most the therapist’s techniques can be augmented with the advancing robot technology. The robotic devices are able of not only providing more persistent and more approachable therapies but still offering other observations into treatment effectiveness based on their knowledge to measure interaction specifications.

Rehabilitation robots operate close to the human user and should be able to deal with various human joints individually and concurrently to imitate human duties. This calls for a robot design that is reliable and user-friendly. Interaction forces between the human user and the robot should also be taken into consideration in controlling the robot in addition to position. Restoring the muscle to perform a specific task perfectly such as standing, walking, eating and gripping is categorized as rehabilitation. Repetitive process during rehabilitation help to reduce the muscle stiffness. The use of mechanical devices are developed to reduce rehabilitation time process, and waiting time as the therapist is not required to be at the site.

1.2 PROBLEM STATEMENT

As time goes by, due to the new era of globalization and improvement of lifestyle, the number of the physiotherapists needed increases as the numbers of post stroke and old patients are increasing. To overcome this problem, engineers have stepped in developing mechanical devices. Due to the increasing needs of the devices, rehabilitation devices were created such as Hand-Wrist Assisting Robotic Device (HOWARD), Biomove Home Device and Hand of Hope. Many portable devices are needed as it allow patients to do their rehabilitation process on their own and for some cases, in their own place. A lot of mechanical devices have been used in Rehabilitation Centre to help physiotherapists assist elderly to do the rehabilitation process. Furthermore, there are many research has been done regarding the design and development of assistive device for post stroke patients but there are several issues with the design. Based on researches that has been reviewed, among the problems captured are

1 Most existing designs of exoskeletons are intricate thus limits the subject movement

2. Therapist observation is still highly required as the current exoskeleton design does not have way to measure the progress of gripping process from the patient.

1.3 RESEARCH OBJECTIVE

The main objective of the research is to develop a prototype of four-fingered hand exoskeleton as a training device to restore the gesture of the hand due to old age with grasping and opening disabilities in their everyday lives. In order to fulfil the research requirement, the research objectives are highlighted as below.

1. To develop a user friendly wearable hand assistive device that can be used for independent therapy.
2. To analyse the performance gripping activities of the use of gripping assistive device.

1.4 SCOPE OF RESEARCH

The scopes of the research are as follows:

- To design an exoskeleton using Solidwork software simulation.
- To ensure the exoskeleton can do extension and flexion in vertical mode.
- The exoskeleton only use proximal and intermediates phalanges
- To use sensor for the purposed mechanism movement control.

1.5 RESEARCH FLOW

This chapter is focus on the procedure of the research, conceptual design and component selection. Several methods have been taken into consideration based on Chapter 2 Literature Review. The work in this chapter focuses on building, development and prototyping the gripping assistive device. To achieve the objective of this research, there are many phases need to be adopted.

The first phase focuses on literature survey on the technical and scientific papers. Investigation on suitable literature is done to obtain technical and scientific information and relevant for the systems based on the objectives. This research will be focuses on the hand and rehabilitation control system.

The next phase is about the design of the exoskeleton. In this research, the exoskeleton is designed using Solidwork. The basic design was adopted based on the designs obtained from the literature review. The third phase is a development of the exoskeleton. The exoskeleton is developed based on the design from the Solidwork software. The development is focusing on the component selection, assembling the parts of exoskeleton and the simulation of the hardware.

The fourth phase is data collection. The data is evaluated by using sensors and make some improvement if necessary. The last phase is a documentation of the research. The flowchart of research methodology will be shown in Figure 1.1.

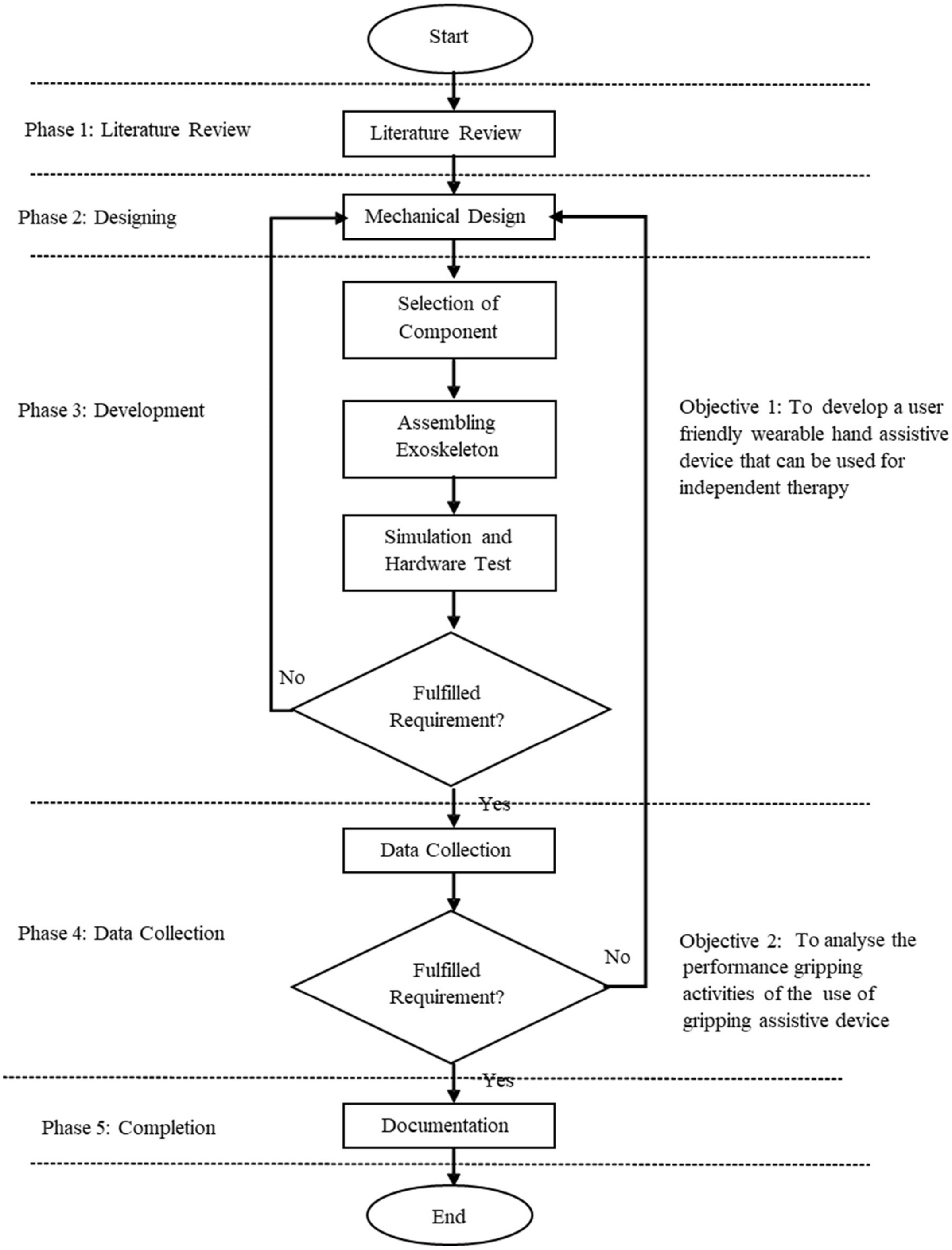

Figure 1.1 Flowchart of Research Methodology

1.6 THESIS ORGANIZATION

Chapter 1: This chapter discusses about the background of the research and the available rehabilitation process, the purpose of the research. The problem statement is highlighted in the chapter leads to the objectives of the research. Then the research methodology explains on how the research had been conducted. Finally, the scope of the research is laid out.

Chapter 2: This chapter discusses about literature review. Research papers that discusses the same or similar research area within the finger rehabilitation, robotics hand and wearable robotics devices is reviewed based on their objectives, methodologies, problems faced and the components used.

Chapter 3: This chapter explains the design involved on the mechanical and electrical system. The design, components and materials selection are elaborated here. The simulation of extension and flexion of the exoskeleton is shown here and the electrical system is presented the selection of actuators, sensors and type of wires is explained through this chapter.

Chapter 4: Chapter 4 emphasizes on the result based on the design from Chapter 3 and the analysis that has been done.

Chapter 5: Chapter 5 is about the conclusion and some recommendation for future plan of this research.

CHAPTER TWO

LITERATURE REVIEW

In this chapter, the existing proposed approaches are briefly presented and reported which constitutes for dealing with finger rehabilitation. The existing proposed approaches that are reviewed in this chapter covers investigation, analysis or comparison that is significant of developing an exoskeleton for rehabilitation. Finger based rehabilitation has been done by various researchers where most research was their own methods as the mechanism of rehabilitation process with same objective which is to reduce the involvement of therapist. This chapter will briefly explain the various rehabilitation process, hand anatomy, similarities and differences explored by other researches which leads to this research work.

2.1 HAND ANATOMY

To design the exoskeleton, human hand anatomy has to be studied extensively (Rahman & Al-Jumaily, 2013). The hand has 27 of total bones where eight of them are carpals bone, five in the metacarpals and fourteen remaining is proximal phalanges (PP), middle phalanges (MP) and distal phalanges (DP) (Shahrol Mohamaddan, 2008) Normal human have 5 digits in each hand which consist of four digits (index finger, middle finger, ring finger and little finger) with three phalanges (PP, MP and DP) and one digits (thumb) with only two phalanges (PP and DP). There are joints to connect different phalanges which are Metacarpophalanges (MCP) joints that connect metacarpals with PP, proximal inter-phalangeal (PIP) joints that connect PP and MP and distal inter-phalangeal (DIP) joints that connect MP and DP. PIP is not present in thumb since thumb does not has MP (Surendra WA, Tjahyono AP, 2012). From previous studies, it can be concluded that our finger contain 3 joints and 3 links for every part of the fingers and 2 joints and 2 links for thumbs. Based on the structure of the hand, each part of the metacarpals bones contain forces and torque which can produce certain movements.

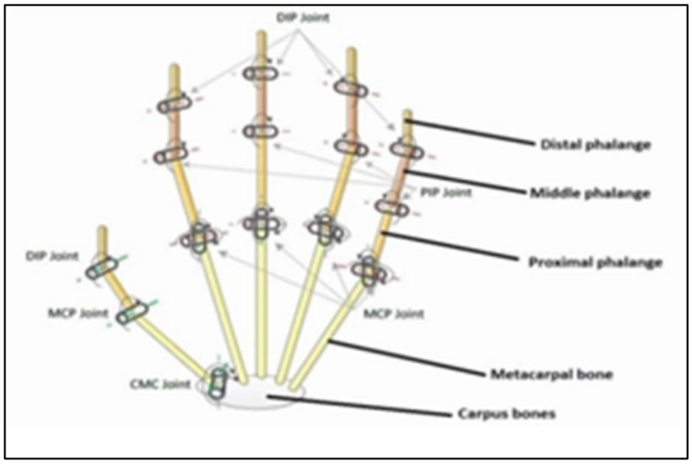

Figure 2.1 Joints in human skeletal system (Surendra WA, Tjahyono AP, 2012)

2.2 HAND FORCES AND TORQUE

For the force of the hand, every part of the finger has its own forces. There are lowest contact forces in human hand during gripping (Kargov, Pylatiuk, Martin, Schulz, & Döderlein, 2004). There are 20 positions where the average of the contact force is 0.8N. Additionally, the distal phalanx of the middle and ring finger, and thumb has the highest average forces. The sum of forces is 16.7N while the minimum force at fingertips is 6.3N.