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Signature :

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**PORTABLE PHYSIOTHERAPY LIMBS REHABILITATION ROBOT:
STRUCTURAL DESIGN**

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**A report submitted in partial fulfilment of the requirements for the degree of Bachelor in
Mechatronic Engineering**

**Faculty of Electrical Engineering
UNIVERSITI TEKNIKAL MALAYSIA MELAKA**

2013

I declare that this report entitle “Portable Physiotherapy Limbs Rehabilitation Robot: Structural Design” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

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ACKNOWLEDGEMENT

I take this opportunity to express my profound gratitude and deep regards to my supervisors, Dr. Ahmad Zaki and Pn Nurdiana Nordin for their exemplary guidance, monitoring and constant encouragement throughout the course of this final year project. The blessing, help and guidance given by them time to time shall carry me a long way in the journey of life on which I am about to embark.

Lastly, I thank almighty, my parents, brother, and friends for their constant encouragement without which this assignment would not be possible.

ABSTRACT

A power-assist robot - Portable Physiotherapy Limbs Rehabilitation Robot (PPLRR) is developed to provide physiotherapy treatment for people with limbs disabilities. A huge number of disabled people are unable to receive physiotherapy treatment due to barriers such as physical disability, insufficient physiotherapist and facility, and difficulty in transportation. Most physiotherapy facility available in the market is too bulky and expensive which is not suitable for home use either or equipment unable to control range of motion with simple function. The invention of a home-based physiotherapy robot could increase chances of physiotherapy for disabled people. This study will focus on the development of mechanical structure of PPLRR which includes design and construct the overall robot structure which is suitable for home use. To control and enhance the range of motion exercise, linear slider paddle is designed and developed which is able to move linearly during cyclic motion. Electrical connection through rotating assembly is required for connecting sensors and components on linear slider paddle. The main cyclic motion for cycling patient's limbs is driven by a power transmission system which converts electric energy to mechanical motion. All the structure design is design with computer aided drawing (CAD) software after doing research and study in dynamics and mechanism. At the end of this project, a robot structure that suit disabled people's needs with linear slider paddle will be integrate with integration control and control manipulation for a complete robot to be tested on healthy person for adjustment and calibration before proceed to test on minor disabled patient. PPLRR can benefit many disabled people in the way of considering their needs and convenience, creating more chances of physiotherapy and at the end bringing greater hope of rehabilitation.

ABSTRAK

Projek ini ialah bertajuk “Portable Physiotherapy Limbs Rehabilitation Robot (PPLRR): Structural Design”. Tujuan projek ini adalah untuk merekacipta dan membina sebuah robot mudah alih yang dapat membantu orang kurang upaya menjalani fisioterapi supaya mempercepatkan proses pemulihan mereka. Terdapat ramai orang kurang upaya di dunia ini tidak berpeluang menjalani fisioterapi disebabkan kesukaran bergerak, kemudahan fisioterapi tidak mencukupi dan sebagainya. Kebanyakan kemudahan fisioterapi yang terdapat dalam pasaran terlalu mahal dan saiz besar yang tidak sesuai untuk kegunaan dalam rumah. Oleh itu, ciptaan sebuah robot mudah alih dapat manambah peluang untuk orang kurang upaya menjalani rawatan fisioterapi. Projek ini akan fokus dalam rekacipta dan pembangunan struktur mekanikal robot PPLRR yang sesuai untuk kegunaan dalam rumah. Ciptaan “Linear Slider Paddle” dalam projek ini dapat meningkatkan hasil fisioterapi dalam pemulihan pesakit dengan pengawalan pergerakan anggota badan yang seluruhan. Untuk membina “Linear Slider Paddle” pada pemegang kayuhan, teknologi penyambungan litar elektrik melalui pemasangan berputar diperlukan. Untuk menggerakkan kayuhan kepada pesakit, motor elektrik akan digunakan sebagai penggerak. Robot ini direkacipta dalam perisian melukis teknikal (CAD) selepas menjalani penyelidikan yang menyeluruh. Projek ini akan berintegrasi dengan dua projek lain iaitu integrasi litar sensor dan pengawalan perisian untuk menyempurnakan robot automasi ini. Diharapkan robot PPLRR ini dapat membantu orang kurang upaya untuk mempercepatkan pemulihan dan mendapat kehidupan yang lebih baik.

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LIST OF ABBREVIATIONS

PPLRR	-	Portable Physiotherapy Limbs Rehabilitation Robot
ROM	-	Range of Motion
CAD	-	Computer aided drawing
AC	-	Alternating current
DC	-	Direct current
cm	-	Centimetre
PVC	-	Polyvinyl chloride
LED	-	Light emitting diode
PCB	-	Printed circuit board
3D	-	three dimensions
CNC	-	Computer numeric control
ADC	-	Analogue to digital conversion

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CHAPTER 1

INTRODUCTION

1.1 Motivation

According to the World Health Organisation, about six hundred and fifty million (650,000,000) people live with disabilities of various types, and the number is increasing due to the rise of chronic diseases, injuries, car crashes, falls, violence and other causes such as ageing. Of this total, 80% live in low-income countries; most are poor and have limited or no access to basic services, including rehabilitation facilities [1]. Besides this, The World Report on Disability states that more than one billion people in the world who are disabled, 110-190 million encounter significant difficulties in their daily lives [2].

According to a news report on 24th April 2007, titled “Killer stroke: Six Malaysian hit every hour” in TheStar, former Health Minister Datuk Seri Dr. Chua Soi Lek stated Six new cases of stroke occur every hour in Malaysia. He also said that was surprising that about 52,000 Malaysians suffered strokes annually when it is the most preventable of all life-threatening health problems. “In 2005, 17,909 stroke victims were admitted into government hospitals alone throughout the country. Of these, 3,245 of them were fatal. By 2020, this figure is expected to exceed 25,000 every year [3].

Physiotherapy remediates the impairment and promotes mobility thus help those unlucky ones to rebuild their limbs strength in order to obtain a better quality of life. Research shows that disabled people would gain better chances of rehabilitation if they do physiotherapy more frequently. Physical therapy may also be used to prevent contractures (permanent muscular contractions) and deformities of the bones, joints, and muscles that would limit recovery for those who emerge from coma, stroke or spinal injury.

1.2 Problem Statement

The world health organisation (WHO) estimates that more than 10% of our population are disabled (this include all classes of disability regardless of the severity) and people with disability registered with department of Social Welfare as of Mei 2009 in Malaysia is 258,918 [4]. With such a great number of disabled people, hospitals and other healthcare providers are always not enough to accommodate them. The Malaysia Physiotherapy Association (MPA) stated that there is not enough physiotherapist and physiotherapy equipment in Malaysia to provide rehabilitation treatment for disabled people especially in rural areas. The number of physiotherapist in Malaysia as of 31 December 2011 recorded 818, with a profession to population ratio of 1:35407 [5]. The crisis of physiotherapist is much more serious in rural areas leading lower chances of receiving rehabilitation.

There were cases that patients were told they will never walk again on discharge, walking with a mobility aid after undergoing physiotherapy exercise. A study on disabled people using assistive movement training apparatus in the rehabilitation frequently for a period of time showed significant improvements in the walking ability [6]. Even when situation for people with severe neural illness which have very little hope of gaining mobility, passive movements of the lower limbs are possible to relax spastic muscles and keep the joints flexible [7]. Most patients appreciate physiotherapy as they believed the treatment can bring about functional improvement and a source of faith and hope; the exercise component was valued because it was perceived to keep them active and busy and exercise programmes to follow at home were also valued for the activity they gave to each day [8].

There is a situation where disabled people faced difficulties of getting physiotherapy treatment due to their physical disability. Most of them have limited mobility and depends on their care givers for daily activities. Going to receive physiotherapy treatment at specialize centre or hospital is very inconvenient where most of them require ambulance service for transportation. The whole process of transportation can cause discomfort to the patient and any careless in handling the patient can lead to serious injuries.

Physiotherapy is not only for disable people where ageing people could also benefit from receiving the treatment. In 1990, 9% which is equivalent to half a billion of world population were over 60 years old and this figure is expected to increase to 1.4 billion (World Health Organisation, 1994) in 2030. Due to the advancement of medical technology and the resultant improvement in health, as well as declining fertility, developing countries such as Malaysia are ageing much faster than those developed nations. Estimation by year 2020 in Malaysia, 9.5% of its population will be 60 years and over [9]. When human grows older, our body function starts to deteriorate especially for those who lack exercise. The most common problem faced by ageing people is their limbs start losing control and muscle strength. Ageing people undergoing physiotherapy rehabilitation can prevent falls and help them maintain mobility and independence in their homes or in retirement villages [10].

Patients of different medical conditions require different range of motions exercise. The degree of their limbs flexibility is identical depending on their state of rehabilitation. Overstretch exercise will cause injuries or pain while insufficient stretching is not efficient in rehabilitation. Most portable physiotherapy equipment available in the market is unable to provide smart control in range of motion exercise. The range of motion exercise control is only available in those robots with several robotic arms supporting the limb at different positions. This type of robot is very expensive and not suitable for home-use.

Power-assist physiotherapy equipment help a lot in keeping and increasing mobility, improving endurance and therefore contributing to everyday life independence, as well as increasing individual quality of life [6]. Disabled patients need to undergo physiotherapy exercise frequently to increase chances of rehabilitation and recovery.

In order to increase the chances of physiotherapy exercise for disabled patients, portable power-assist equipment that is suitable to utilize at home is recommended.

1.3 Objectives

- a) To design and develop mechanical structure for home-based limbs rehabilitation physiotherapy robot.
- b) To develop linear slider paddle for controlling patient's range of motion during physiotherapy treatment.
- c) To establish electrical connection from a stationary unit to a rotating unit.

1.4 Scope

- a) The robot developed is only a prototype model for limbs physiotherapy testing.
- b) This prototype robot is applicable for people weight less than 70kg.
- c) Home-based robot means robot suitable for home use, size and weight a man can carry, portable enough for carrying around and fit in normal saloon car.
- d) The linear slider paddle has a limited linear motion (15cm).
- e) The sensor control integration and computer interface is done by other projects under the same title Portable Physiotherapy Limbs Rehabilitation Robot.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The literature review of this project focuses in mechanical structural design and some basic knowledge and requirements in physical therapy for designing a physiotherapy robot. Studies are done to learn about needs of disabled people in physiotherapy treatment and the problems or inconvenience in getting this treatment. Considering some difficulties disabled people faced to have physiotherapy treatment, a portable robot that can provide physiotherapy treatment is to be designed. There is a lot of consideration taken into account for a physiotherapy robot which is able to help disabled people solve some problems and difficulties as stated in Problem Statement in the previous section in this report. This literature review is categorized into few parts which include mechanical design consideration, robot structure design consideration, power transmission system and linear slider paddle. Conclusion are made at the end about how to design a physiotherapy robot that is able to provide range of motion (ROM) physiotherapy treatment enhancing disabled patient's rehabilitation in their most convenient way.

2.2 Design Consideration for Limbs Physiotherapy Treatment

The first requirement when creating a new product is design consideration based on the needs of target group of the product. Design consideration are based on few of the following factors: physiotherapy at home, simple and effective power assisted motion, one robot compatible for arms and legs physiotherapy, different physiotherapy modes for patient of different level of rehabilitation, etc. These concerns are made to let disabled patient able to access rehabilitation at home. Then a study about the importance of range of motion (ROM) exercise for disabled patient and how to implement this function in the

robot design. To increase the convenience for disabled patient, the robot is designed to provide physiotherapy treatment for both arms and limbs and suitable for patients of different level of rehabilitation.

2.2.1 Design Consideration for A Home-based Physiotherapy Robot

Physiotherapy equipment for home use enables patients to have daily treatments at convenient times using protocols tailored to their specific needs and anthropometrics (personalization). The robot needs to provide physiotherapy treatment for disabled patient at the comfort of their home; saving time, money and risk of getting injured. Home rehabilitation is running the concept of wellness and part of the contemporary trend of gym and fitness equipment that are capable of being practiced at home.

Disabled people may not be able to build incidental physical activity into everyday life activities by taking the stairs instead of the lift, or walking a few more bus stops, because of impaired mobility or decreased functional capacity [11]. There are many reasons and barriers of disabled people from acquiring physiotherapy rehabilitation treatment: lack of physical access to recreation facilities and to equipment, from the cost of access to suitable programmes, from a range of impairments that hinder exercising in usually accepted formats, from emotional and psychological difficulties of exercising in the public domain, and from a perceived lack of knowledge of staff in recreation facilities to be able to assist those with disability to exercise safely [11].

Convenience of using the robot must be considered in the aspect of how the user setup physiotherapy training for a patient and positioning of the robot for physiotherapy treatment. The size of the robot must be minimal and light weight to ease household user. The robot must be portable for utilization and fit into normal saloon cars which make it portable for travel. User can move the robot around and use it for physiotherapy treatment anywhere. The robot shall be able to place on bed, chair, table, etc. to ease the treatment. It need to be within a size that one man is able of carrying and fit into most houses, along with capability of providing quality physiotherapy exercise and training.

2.2.2 Assisted Motion for Physiotherapy

Physiotherapy generally consisted of stretching the anterior and posterior shoulder girdle, muscle relaxation techniques, motor learning to normalize dysfunctional patterns of motion, and strengthening the rotator cuff and scapular muscles [12]. There are many types of exercising suitable for rehabilitation such as stretching, range of motion exercise and etc. Power assisted equipment are designed to simulate motions of physiotherapy to a patient.

There are many physiotherapy robots available in the market providing different kind of rehabilitation options. Some advance robotic arm with many degrees of freedom can apply great range of motion exercise for disabled patient but at very high cost.



Figure 2.1: A two arm robot assisting patient in range of motion exercise [13]

A very common range of motion exercise for limbs disabled patient is stretching and retracting the limbs continuously. Hence the assisted motion selected for this robot is cyclic motion. This way of physiotherapy is proven to be effective and clear improvements in rehabilitation where patients undergo physiotherapy exercise with the MOTMed movement trainer for a few months [7]. Besides, this mechanism is simple but effective for rehabilitation. The cost of developing this mechanism is relatively low compared to those multiple degree of freedom robot arm for physiotherapy.



Figure 2.2: Cyclic motion exerciser [14]

With a power transmission system in generating circular motion, two paddles are attached to the moving shaft like bicycle cycling system. The mechanism is similar to the cyclic motion exerciser shown in Figure 2.3. Cyclic motion can aid patients in ROM exercise and this is one of the best ROM exercises.



Figure 2.3: A patient doing hand cyclic exercise [11]

2.2.3 Compatible Physiotherapy Treatment for Both Hands and Legs

Disabled people need physiotherapy treatment for all joints of their body to maintain the flexibility. Most joints of human body are at limbs and spine. Majority of the physiotherapy treatment undergone in hospital and specialize centers focus on patient's limbs and spine. Physiotherapist will do range of motion exercise on patient's limbs, moving their limbs in a range that they can afford to do without injuring them.

To design a home-based physiotherapy robot that suit most disabled patient, it must be able to provide physiotherapy treatment for both arms and legs. Upon purchasing one robot and the patient can have physiotherapy treatment for both arms and legs at home. They do not need to purchase two separate physiotherapy equipment for arms and legs which may cost more and consume space.

In order to make the robot convenient to user, only some small adjustment is required to change from arms physiotherapy to legs physiotherapy. The adjustment on the robot could interchange the handle for hand or leg paddle. Besides changing paddle, the position of the robot needs to be adjusted to suit the patient. The patient must be in a comfortable position when doing physiotherapy treatment as this can enhance the progress and prevent injuries. For example, a patient must sit upright to undergo hands physiotherapy treatment with the robot placed in front facing the patient. For legs physiotherapy, the patient could be lying down on the bed and the robot place at the end of the bed at the same level with the patient attaching their foot on the paddle or the patient sit upright with the robot placed on the floor.