DESIGN AND DEVELOPMENT OF PORTABLE HOME BASED REHABILITATION DEVICE

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Alhamdulillah in the name of Allah, I would like to show my gratitude to the almighty Allah S.W.T for the endless, guidance, knowledge and healthiness and giving me strength and power to complete this important stage in my life education. I would like to take this opportunity to express my deepest gratitude to my supervisor ASSOCIATE PROF DR. MUHAMMED MAHADI BIN ABDUL JAMIL for his precious guidance, intuitive commands and good suggestions in completing this project. In order to undergo this final year project, there are a number of people who really help me and stand by me along my journey staring from the beginning of my study till the end of this project especially my beloved friend ABDULHAKIM AL-EZZY. Without their help, support and their contribution into my project, my project will not be done in such as this amazing work. From the bottom of my heart I would like to express my thankfulness and love to my beloved family for their great support and blessings since the day I stared my life. My most grateful and respect to my father, mother, my uncles Salah, Yasser, Taha, Abdulwahid and my other uncles, my brother SAMI, my sisters and all my friends who stranded by me and supported me to pass through this critical time. For those names could not be mentioned here one by one, it is a great pleasure to show u my great respect for you all. Thanks for everyone involved in this project direct or indirect for their help and contribution.
ABSTRACT

A constant monitoring process for arm rehabilitation activities is very significant to impart information of rehabilitation results to be analyzed by physical therapist. We propose here a new type of leg rehabilitation system. The aim of the system is to realize the multiple-degree-of-freedom (DOF) training of a leg by manipulating the patient's leg with wires. The majority of current portable orthotic devices and rehabilitative braces provide stability, apply precise pressure, or help maintain alignment of the joints without the capability for real time monitoring of the patient's motions and forces and without the ability for real time adjustments of the applied forces and motions. Improved technology has allowed for advancements where these devices can be designed to apply a form of tension to resist motion of the joint. The related studies to home-based rehabilitation process have shown improvement in promoting human movement recovery. However existing rehabilitation devices are expensive and need to be supervised by physical therapist. Some devices are not so efficient to be used at home due to large size and complexity. So this project aims to design and develop monitoring home-based device for arm rehabilitation. There are three basic units in designing this device which are sensory unit, main unit, and data logging unit. The sensory unit contains of flex sensor, five force sensitive resistors and accelerometer. Main unit is called data processing unit where this done by using Arduino Mega microcontroller. Data from Arduino is logged into PC to be shown in real time by Microsoft visual basic. Also data can be stored in SD card in excel file format to send it to doctors for analysis purpose. This device should be portable, affordable and determine a human movement analysis by determining the sensors characteristics.
ABSTRAK


Terdapat kajian sebelum ini berdasarkan proses pemulihan yang di lakukan di rumah telah menunjukkan peningkatan dalam mempromosi penyembuhan pergerakan tubuh manusia. Walaubagaimanapun kehadiran peranti pemulihan ini adalah mahal dan memerlukan permerhatian dari ahli terapi atau fisiologi. Sesetengah peranti adalah tidak begitu tepat untuk di gunakan di rumah kerana saiz yang besar dan kompleks. Maka projek ini ada bertujuan untuk mereka dan membentuk peranti yang boleh digunakan di rumah untuk pemulihan lengan .

Terdapat tiga unit asas untuk mereka peranti ini adalah seperti sensor, unit utama, dan unit data log. utama di panggil sebagai unit pemprosessan data di mana ia dilaksaan menggunakan Arduino Mega pengawal mikro. Data daripada Arduino alah di buka di PC untuk paparan masa sebenar untuk “Microsoft visual basic” atau visual asal Microsoft. Data juga juga boleh di simpan di kad SD dalam fail format excel untuk di hantarkan kepada doktor untuk kegunaan analisis. Peranti ini sepatutnya boleh mudah alih, berkemampuan dan memastikan analisis pergerakan tubuh manusia oleh penentu sifat sensor.
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1.0 Background of study

Stroke is a serious, life-threatening medical condition that occurs when the blood supply to part of the brain is cut off. According to the national registration department, stroke has become the third main causes of death for the past 5 decades in Malaysia. Due to that we can conclude that a large number of patients who recovered from this disease may suffer from post-stroke symptoms. These symptoms include trouble with speaking and understanding, paralysis or numbness of the face, arm or leg, trouble with seeing in one or both eyes and most seriously symptom is sudden loss of brain functions witch caused by some disturbances in supplying blood to the brain. These diseases affect the quality of patients' life where is gives difficulties for them to carry out activities of daily living. Basically, there are three types of treatments for stroke: prevention, therapy directly after stroke, and post-stroke rehabilitation. Post-stroke rehabilitation may help stroke patients to be recovered from the stroke disease and make the patient walk again.
Post stroke Rehabilitation is the process of combining pharmacological (prescription medications) and psychotherapeutic treatments to address substance abuse disorders. Rehabilitation is a very helpful process for stroke patient to gain the fitness and ability to do the activities that they used to do previously. Rehabilitation process are based on clinical assessment tools which can be executed by home-based and done at rehabilitation center which may be costing and timing consumption.

Usually stroke patients are facing difficulties with daily movements and activities which can be decreased through rehabilitation therapy during the critical post-stroke period. Such rehabilitation therapy involves carefully designed repetitive exercise, which can be passive and active. In passive exercise, the therapist or a robot actively helps the patient to repeatedly move the stroke-affected limb as prescribe. In active exercises, the patient does the work by him/herself, with no physical assistance. From that particular therapist, assistive robotic technology has the potential to provide novel means for monitoring, motivating and coaching.

1.1 Research objective

The main objectives of this project are to:

- To design a portable, affordable and simple home-based rehabilitation device for leg rehabilitation to improve daily rehabilitation activities.
- To develop the system that assists the stroke patient with leg disability and help therapist for monitoring and logging data analysis.
- Implement a sensory unit for portable leg rehabilitation device by assessed two flex sensor, three force sensitive resistors (FSR) and accelerometer which are connected to arduino Mega and interface the Arduino with Microsoft Visual Basic (VB) software to show and analyze the data.

1.3 Problem statement
Recently, several methods of training have been found for physical therapy such as using the rehabilitation devices at clinic or hospitals. However most of them are expensive and need to be supervised by physical therapist. Moreover these rehabilitation devices used high power consumption to perform the therapy and having a complex control system. Some devices also are not so efficient to be used at home due to large size and complex system. These problems may be solved by proposing a new design of mechanism for the rehabilitation device. This device is home-based monitoring for leg rehabilitation which is affordable and assessed with sensory unit and equipped with an Arduino which read the analog data and store data in Secure Digital (SD) card in excel file format to be logged into personal computer (PC).

1.4 Scope of the project

In this study, designations of the assistive the portable home-based rehabilitation system only focus on the one side of the leg. It will encompass the development of mechanism at knee and knee joint. In order to make sure the project will achieve the objectives stated, the scopes of this project comprise the following aspects:

The scopes of this project are:

- The rehabilitation system will be applicable & implemented for medical care.
- This study will focus on electrical activity and movement by the unit sensors which are flex sensors, FSR and accelerometer.
- This sensory unit equipped with an Arduino which read the analog data and store data in SD card in excel file format to be logged into PC.
- Microcontroller unit:
The microcontroller used in this project is Arduino microcontroller which will be used to process the analog data from the sensory unit into PC and SD card.

- **Result display**
  
  Microsoft VB is interfaced with arduino to show reading of data into a PC and saved into SD card.
CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This chapter presents review of journal articles, related papers, internet articles and previous related thesis on leg rehabilitation assistive device. In this chapter, few papers and journals will be considered due to the extensive researches related to this field. It will also describe the components and circuits that are used to design and develop the device which may ease the way for further upgrade in development of leg rehabilitation assistive device in the future.

As a general overview, we will state our work to design and develop leg rehabilitation monitoring device that is aimed to provide continuous rehabilitation method in health care area to assist patients after stroke. This main goal of this project is to design monitoring device with multi-sensors (flex sensor, FSR and accelerometer) and data logging capability. The sensors unit is equipped with an Arduino which read the analog data and transmit data to be logged into PC. In this project we will implement multi-sensors capabilities to get electrical signal from these sensors through distinctive human movement activities to provide and analyze information from each sensor.
2.1 Stroke

2.1.1 History of stroke

More than 2,400 years ago the father of medicine, Hippocrates, recognized and described stroke—the sudden onset of paralysis. Until recently, modern medicine has had very little power over this disease, but the world of stroke medicine is changing and new and better therapies are being developed every day. It is called apoplexy by the Greeks which means "struck down by violence" a general term that physicians applied to anyone suddenly struck down with paralysis. The term apoplexy did not indicate a specific diagnosis or cause because many conditions can lead to sudden paralysis. Centuries later, in the mid-1600s, (AbeyAlbert, m. d, 2013) dedicated his life to the dissection of corpses in the morgue of the University of Padua in Italy. Abey (2013), discovered that something disrupted the blood supply in the brains of people who died from apoplexy. In some of these cases, the arteries were blocked. In others, there had been massive bleeding into the brain tissue. The first person to investigate the pathological signs of apoplexy was Johann Jacob Wepfer, whos studied medicine and was the first to identify postmortem signs of bleeding in the brains of patients who died of apoplexy.

Medical science would eventually confirm Wepfer's hypotheses, but until very recently doctors could offer little in the area of therapy. Over the last two decades basic and clinical investigators, many of them sponsored and funded in part by the National Institute of Neurological Disorders and Stroke (NINDS), have learned a great deal about stroke. They have identified major risk factors for the disease and have developed surgical techniques and drug treatments for the prevention of stroke. But perhaps the most exciting new development in the field of stroke research is the recent approval of a drug treatment that can reverse the course of stroke if given during the first few hours after the onset of symptoms.

Today, there is a wealth of information available on the cause, prevention, risk, and treatment of stroke. Most stroke victims now have a good chance for survival and
recovery. Immediate treatment, supportive care, and rehabilitation can all improve the quality of life for stroke victims.

2.1.2 Stroke

A stroke happens when the blood which supply to part of the brain is suddenly interrupted or when a blood vessel in the brain bursts, spilling blood into the spaces surrounding brain cells. In the same way that a person suffering a loss of blood flow to the heart is said to be having a heart attack, a person with a loss of blood flow to the brain or sudden bleeding in the brain can be said to be having a "brain attack". Stroke is a sudden loss of brain function caused by the interruption of blood flow to the brain (ischemic stroke) or the rupture of blood vessels in the brain (hemorrhagic stroke). A stroke can affect any number of areas including the ability to move, see, remember, speak, reason, and read and write.

There are two forms of stroke: ischemic - blockage of a blood vessel supplying the brain, and hemorrhagic - bleeding into or around the brain. An ischemic stroke occurs when an artery supplying the brain with blood becomes blocked, suddenly decreasing or stopping blood flow and ultimately causing a brain infarction. While hemorrhagic stroke is occurred when an artery in the brain bursts, blood spews out into the surrounding tissue and upsets not only the blood supply but the delicate chemical balance neurons require to function.

Even though a stroke occurs in the unseen reaches of the brain, the symptoms of a stroke are easy to spot. They include sudden numbness or weakness, especially on one side of the body; sudden confusion or trouble speaking or understanding speech; sudden trouble seeing in one or both eyes; sudden trouble walking, dizziness, or loss of balance or coordination; or sudden severe headache with no known cause. All of the symptoms of stroke appear suddenly, and often there is more than one symptom at the same time.
2.1.3 Symptoms of stroke

Symptoms of stroke appear suddenly, there are many symptoms such as:

✓ Trouble with speaking and understanding: Stroke patient may experience confusion and may slur words or have difficulty understanding speech.

✓ Trouble with walking: Patient may stumble or experience sudden dizziness, loss of balance or loss of coordination.

✓ Headache: A sudden, severe headache, which may be accompanied by vomiting, dizziness or altered consciousness, may indicate that he having a stroke.

✓ Trouble with seeing in one or both eyes: Patient may suddenly have blurred or blackened vision in one or both eyes, and may see double.

✓ Paralysis or numbness of the face, arm or leg: Patient may develop sudden numbness, weakness or paralysis in your face, arm or leg, especially on one side of your body. He/she might try to raise both his/her arms over his/her head at the
same time. If one arm begins to fall, he/she may be having a stroke. Similarly, one side of his/her mouth may droop when he/she try to smile.

Figure 2.2: First Signs of Stroke Symptoms
(http://www.medicalsymptomsguide.com/symptoms-before-a-stroke.html)

2.1.4 Causes of stroke

There are several diagnostic technique and imaging tools that help the physicians to diagnose the causes of stroke quickly and accurately. A stroke may be caused by a blocked artery (ischemic stroke) or a leaking or burst blood vessel (hemorrhagic stroke), as what has been described previously. Ischemic stroke, about 85 percent of strokes are ischemic strokes. Ischemic strokes as shown in figure 2.3, occur when the arteries to your brain become narrowed or blocked, causing severely reduced blood flow (ischemia). The most common ischemic strokes include:

1. Thrombotic stroke which is a thrombotic stroke occurs when a blood clot (thrombus) forms in one of the arteries that supply blood to your brain. A clot
may be caused by fatty deposits (plaque) that build up in arteries and cause reduced blood flow (atherosclerosis) or other artery conditions.

2. Embolic stroke which is an embolic stroke occurs when a blood clot or other debris forms away from your brain, commonly in your heart, and is swept through your bloodstream to lodge in narrower brain arteries. This type of blood clot is called an embolus.

Aside from Ischemic stroke and hemorrhagic stroke, stroke also can be caused by aneurysm. Aneurysm occurs on the wall of a blood vessel in the form of a balloon-like swelling which is filled with blood (Fitzhenry, 2009). The force generated by heart's blood pumping activity can affected a weak spot on a blood vessel, where over a period of time, a balloon shape or swelling will be formed on this weak spot. At the end, the wall will be ruptured due to its weak condition.

Hemorrhagic stroke as shown in figure 2.3 occurs when a blood vessel in your brain leaks or ruptures. Brain hemorrhages can result from many conditions that affect your blood vessels, including uncontrolled high blood pressure (hypertension) and weak spots in your blood vessel walls (aneurysms).

**Figure 2.3:** Main causes of stroke (Fitzhenry, 2009)
A less common cause of hemorrhage is the rupture of an abnormal tangle of thin-walled blood vessels (arteriovenous malformation) present at birth. Types of hemorrhagic stroke include:

- **Intracerebral hemorrhage**: In an intracerebral hemorrhage, a blood vessel in the brain bursts and spills into the surrounding brain tissue, damaging brain cells. Brain cells beyond the leak are deprived of blood and damaged. High blood pressure, trauma, vascular malformations, use of blood-thinning medications and other conditions may cause intracerebral hemorrhage.

- **Subarachnoid hemorrhage**: In a subarachnoid hemorrhage, an artery on or near the surface of your brain bursts and spills into the space between the surface of your brain and your skull. This bleeding is often signaled by a sudden, severe headache.

A subarachnoid hemorrhage is commonly caused by the bursting of a small sack-shaped or berry-shaped out pouching on an artery (aneurysm) in the brain. After the hemorrhage, the blood vessels in your brain may widen and narrow erratically (vasospasm), causing brain cell damage by further limiting blood flow.

- **Vacuities**: Another rare cause of stroke is vacuities, a condition in which the blood vessels become inflamed causing decreased blood flow to brain tissue.

- **Migraine headache**: There appears to be a very slight increased occurrence of stroke in people with migraine headache. The mechanism for migraine or vascular headaches includes narrowing of the brain blood vessels. Some migraine headache episodes can even mimic stroke with loss of function of one side of the body or vision or speech problems. Usually, the symptoms resolve as the headache resolves.
2.1.5 Effect of stroke

The effects of stroke (brain attack) vary from person to person based on the type, severity, location, and number of strokes. The brain is extremely complex and each area of the brain is responsible for a special function or ability. When an area of the brain is damaged, which typically occurs with a stroke, impairment may result. Impairment is the loss of normal function of part of the body. Sometimes, impairment may result in a disability, or inability to perform an activity in a normal way.

2.1.6 Stroke Rehabilitation

The purpose of rehabilitation is to return the stroke patient as close as possible to their life and level of function before the stroke. The success of that goal depends upon the underlying health of the patient and severity of the stroke.

Singh et al (2013) mentioned that, rehabilitation engineering is a subfield of engineering sciences that deals with designing and applying its principles to obtain technical solutions for people with disabilities. It usually entails various regions of applications such as mobility, communications, hearing, vision, cognition, and activities associated with employment, independent living, and education.

Proper functioning and movement of limbs has always been the primary aim of rehabilitation engineering. This aspect supported with factors such as low cost, cosmetic appeal, and easy usage would result in an ideal device that can be used for practical purposes (Singh et al, 2013). They also mentioned that the rehabilitation treatment can be adopted for either upper limbs or lower limbs or both. Focusing on the functional restoration of upper limbs, two facets that are usually observed in upper limb movement are: Hand grasp space of the object and the force required to hold onto the object. Instruments which are used for upper limb rehabilitation these days do not record the
forces exercised for various activities. They simply testify the force employed either by each individual finger or overall pinch and grip strength. In addition, they are expensive and bulky, henceforth posing to not be a practical option for daily use. Consequently, this work aims to overcome these setbacks by providing a low cost, easy to use solution which could also be useful when modeling a robotic arm or palm for object manipulation.

To enhance brain function to detect leg motion, motion tracking can be realized in several ways. Tracking systems are generally categorized as either nonvisual tracking systems (e.g., based on inertial sensors or data gloves) or visual systems (e.g., camera). The latter can further be subdivided into marker-based and marker-free systems (conventional video camera). Each method has different merits and limitations. (Reinhold Scherer et al., 2012).

In order to develop such predictive models, Reinhold et al. (2012) proposed that we need a longitudinal study design and the possibility of monitoring the brain activity of individuals during rehabilitation. Multichannel electroencephalography (EEG) has emerged as the most important non-invasive signal source for functional brain mapping (FBM) and brain-computer interfacing (BCI) in humans. Following the state of the art in stroke rehabilitation, training of leg function ought to be task-oriented. This means that training should be relevant to daily life tasks and preserve their complexity (Markopoulos, P et al., 2011).

According to Lim, C. K., Chen et al. (2010)taking the rehabilitation practice at home can help stroke patients with movement disability to regain the motor skill. Existing systems for rehabilitation is either too costly, or complicated and bulky to be efficiently employed for personal use at home. Rehabilitative therapy is essential to the treatment process to help stroke survivors regain their limb functions. The most common objective of stroke rehabilitation is to achieve a level of physical and psychological functioning that allows patients to return home and perform everyday activities. Rehabilitation exercises are thus specifically designed to match the goals of each individual.

About rehabilitation programs LambertoPiron et al., (2006) said, telerehabilitation program may spare the available resources since allows
physiotherapists and physicians to rehabilitate and monitor the patients remotely from rehabilitation facilities.

Lauri Connelly et al (2009) had summarized that hand impairment is common following stroke and is often resistant to traditional therapy methods. Successful interventions have stressed the importance of repeated practice to facilitate rehabilitation. Thus, they have developed a servo controlled glove to assist extension of individual digits to promote practice of grasp-and-release movements with the hand. In this project we also will use FSR to measure grasp and release movements with hand.

2.1.7 Body Sensor Network

Body sensing technique in electronic entertainment has realized the association of new era technology with rehabilitation medical care to set up virtual reality together with the use of Kinect to be applied in rehabilitation training for stroke patient. As compared to traditional expensive rehabilitation equipment, it has the advantages of low price and clinical practical utility. Its interface design is active and attractive, and is converted from boring to happy state. After completing rehabilitation training mission, medical care rehabilitation quality can indeed be effectively enhanced,(Yeh, Shih-Ching, et al, 2012, June).

The last decade has witnessed a rapid surge of interest in new sensing and monitoring devices for healthcare and the use of wireless wearable devices for clinical applications. One key development in this area is implantable in vivo monitoring and intervention devices. To address general issues related to wearable and implantable sensors and harness allied technologies that underpin the development of pervasive sensing for healthcare, wellbeing, sports and other applications that require “ubiquitous” and “pervasive” monitoring of physical, physiological, and biochemical parameters in any environment and without activity restriction and behavior modification.
Key research activities in the field include miniaturized biosensor design suitable for both wearable and implantable devices, biocompatibility and materials to ensure long-term deployment, low-power wireless communication, integrated circuits and systems, power scavenging techniques from the body, autonomic sensing and standards and integration.

2.2 Literature Review

To enhance brain function to detect leg motion, motion tracking can be realized in several ways Tracking systems are generally categorized as either nonvisual tracking systems (e.g. based on inertial sensors or data gloves) or visual systems (e.g. camera). The latter can further be subdivided into marker-based and marker free systems (conventional video camera). Each method has different merits and limitations. (Reinhold Scherer et al, 2012). In order to develop such predictive models, Reinhold et al (2012) proposed that we need a longitudinal study design and the possibility of monitoring the brain activity of individuals during rehabilitation. Multichannel electroencephalography (EEG) has emerged as the most important non-invasive signal source for functional brain mapping (FBM) and brain-computer interfacing (BCI) in humans. Following the state of the art in stroke rehabilitation, training of leg function ought to be task-oriented. They created a brain computer interface Systems (BIC) which let users convert thoughts into actions that do not involve voluntary muscle movement. The systems offer a new means of communication for those with paralysis or severe neuromuscular disorders. This technology is a relatively new, fast-growing field of research and applications with the potential to improve the quality of life in severely disabled people. To date, several prototypes exist, but most work only in a laboratory environment. Before a BCI can be used for communication and control at home, research must solve several problems. An important next step is to establish protocols for easily setting up and using BCI systems in a practical environment. Many features, such as electrode positions and frequency components, must be automatically selectable.
for particular motor imagery. The system must use the fewest number of recording electrodes possible, striving for the optimal single EEG channel. Finally, training time must decrease, perhaps through game-like feedback and automatic detection of artifacts, such as uncontrolled muscle activity. With these improvements, which are on the horizon, it is expected to see practical BCI systems for a wide range of users and applications. This means that training should be relevant to daily life tasks and preserve their complexity (Markopoulos, P et al, 2011).

![Brain interface system](image)

**Figure 2.4:** Brain interface system (Markopoulos, 2011)

Stroke patients need to receive repetitive and intensive therapy in order to regain mobility and ability. Robot-assisted rehabilitation is an active area of research. Cheap robotic leg rehabilitation devices should be developed to meet the demands and assist most patients. A low cost hip-knee exoskeleton prototype powered by pneumatic muscles was developed by Jian Huang et al (2016). On this basis, Functional Electrical Stimulation (FES) induced paralyzed muscles to realize ankle joint rehabilitation
training. As both of pneumatic muscle and FES induced muscle possess highly nonlinear characteristics, a sliding control algorithm called Chattering mitigation Robust Variable Control was applied to leg hybrid rehabilitation. The combination of exoskeleton and FES is a promising way to reduce the cost and the complexity of designing hip-knee-ankle exoskeleton. The proposed hybrid method is verified by treadmill-based gait training experiments. This work, so as to make clear this integrative rehabilitation strategy cooperation of hip-knee exoskeleton and FES electrically evoked ankle joint to realize hip-knee-ankle hybrid rehabilitation trainings, we report a newly developed pneumatic muscle driven hip-knee exoskeleton integrated with FES. In Section II, the dynamic model of single joint of hip-knee exoskeleton powered by a pair of pneumatic muscles is built, and corresponding algorithm is derived electrically stimulated models of three muscles actuating ankle dorsiflexion/plantar-flexion are built, and Hammerstein muscle structures are identified through electrical stimulation experiments. Section III reports the experimental results. Due to the high costs and large weight of rehabilitation devices, most wearable lower limb rehabilitation robots are hard for stroke patients to accept and use. Pneumatic muscle is a kind of lightweight and low cost actuator, and suitable for developing human-machine interaction robotic devices. In consideration of their own characteristics of stroke subjects, our proposed integrative strategy is using hip-knee exoskeleton with FES electrically evoked paralyzed ankle muscles to realize hip-knee-ankle joint training, which is a promising approach to alleviate the size and mechanical complexity of the robot, thereby the cost of the rehabilitation robot.

The future research was discussed for design principle of how to take advantage of each technique in developing a more functional effective hybrid FES and robot assisted system for lower limb rehabilitation training in the future.
According to Lim, C. K., Chenet al (2010) taking the rehabilitation practice at home can help stroke patients with movement disability to regain the motor skill. Existing systems for rehabilitation is either too costly, or complicated and bulky to be efficiently employed for personal use at home. Rehabilitative therapy is essential to the treatment process to help stroke survivors regain their limb functions. The most common objective of stroke rehabilitation is to achieve a level of physical and psychological functioning that allows patients to return home and perform everyday activities. Rehabilitation exercises are thus specifically designed to match the goals of each individual.

Development of an enhanced leg muscle rehabilitation system had been introduced by Huang et al (2006). The researchers aim to develop an enhanced rehabilitation and assessment system for some specific people with impaired leg muscles, and for people who need to improve their leg muscle function. Through interactive design and real time evaluation, medical staff can totally control the training situation for patients and therefore provide a better training program, so that overall a better treatment performance can be achieved. The system categorized of four major parts. Sensory and signal conversion circuits convert the lever leg lengths and muscle strengths of the leg into a proper electronic signal and then deliver this to the computer. Then, the intelligent and interactive interface design lets a trainee complete the training process independently without the involvement of medical staff. In addition, the trainee can see the training results at the end of the training process on the computer screen. The training protection and evaluation mechanism effectively monitors the training situation,
based on the individual status settings by the medical staff, and thus any further impairment can be avoided. The database management system is developed to store related personal data, system settings and training results, which can then be retrieved for control and assessment. In comparison to similar equipment the proposed system demonstrates a much better performance, particularly in system functions, accuracy, operation and costs.

Wearable health monitoring systems allow an individual to closely monitor changes in her or his vital signs and provide feedback to help maintain an optimal health status. If integrated into a telemedical system, these systems can even alert medical personnel when life-threatening changes occur. In addition, patients can benefit from continuous long-term monitoring as a part of a diagnostic procedure, can achieve optimal maintenance of a chronic condition, or can be supervised during recovery from an acute event or surgical procedure (Milenkovic et al, 2006), he also mentioned that, during the last few years there has been a significant increase in the number of various wearable health monitoring devices, ranging from simple pulse monitors, activity monitors, and portable Holter monitors, to sophisticated and expensive implantable sensors. However, wider acceptance of the existing systems is still limited by the following important restrictions. Traditionally, personal medical monitoring systems, such as Holter monitors, have been used only to collect data. Data processing and analysis are performed offline, making such devices impractical for continual monitoring and early detection of medical disorders. Systems with multiple sensors for physical rehabilitation often feature unwieldy wires between the sensors and the monitoring system. These wires may limit the patient’s activity and level of comfort and thus negatively influence the measured results. In addition, individual sensors often operate as stand-alone systems and usually do not offer flexibility and integration with third-party devices.

The process that we apply to monitor leg rehabilitation is the same with leg rehabilitation process, and this what Kushsaity et al (2015). Leg rehabilitation activities are necessary to be continuously monitored in order to provide information of rehabilitation results to be examined by physical therapist. The determination of monitoring is to enhancing rehabilitation process. Moreover, a portable and simple
home-based rehabilitation device can help patients to improve daily rehabilitation process activity. Some earlier studies regarding home-based rehabilitation process have shown improvement in promoting human movement recovery. This work focuses on the development of a measurement by using leg guard and Smart Glove or Rehabilitation Glove, to assist stroke patient because of some complications such as accident and disease. This study concourses on the method and application of mechanical equipment, sensors equipped Rehabilitation Glove measurement gripping activities. The devices will move based on a human operator's lower leg and leg movement using the Rehabilitation Glove. The system development involves a Microcontroller and HyperTerminal as a core processing for the instrumentation, communication and controlling applications. A series of bend or known as flex force sensors are fitted in a Rehabilitation socks to get reading from the movement of human leg. The quality of the force feedback is strongly affected by the maximum torque measurable by the Rehabilitation Glove and the performance of the force controller. Finally, the intelligence, learning and experience aspects of the human can be combined with the strength, endurance and speed of the human leg and Rehabilitation sensor in order to generate proper output of this work.

![Figure 2.6: Rehabilitation process of leg (Kushsairy, 2015).](image-url)
The mechanical were analyzed and finalized for designing a workable device. A new approach with four fingers and a thumb gripper had been developed and controlled to ensure optimum finger gripping and positioning was applied in the Smart Glove (Master) by Ali et al (2015).

The variable grip force feature permits grasping and lifting of fragile objects without crushing them. Leg rehabilitation activities require continuous monitoring process in order to provide accurate information on final rehabilitation results to be analyzed by therapist. The purpose of monitoring is to help them to improve and customize the rehabilitation process. Moreover, a portable and simple home-based rehabilitation device can help patients to improve daily rehabilitation activity. Some previous studies regarding home-based rehabilitation process have shown improvement promoting human movement recovery. But existing rehabilitation devices are expensive and need to be supervised by a physical therapist, which are complicated to be used at home. Some devices are not so efficient to be used at home due to the large size and complex system. In this current work, flex sensor, FSR and accelerometer were assessed in order to be implemented as a sensory unit for a portable leg rehabilitation device. The analog signal from the sensors will be conveyed to an Arduino microcontroller for data processing and logging. The device is equipped with online or portable data logging capabilities which can store daily activity results. The results of rehabilitation activity can be used for further monitoring and analysis. Experiments were carried out to determine the feasibility of each sensor towards the design of the new device. The experiments demonstrate the capabilities of the sensors to produce extended information regarding leg movement activities which can be implemented in the design.
Reinkensmeyer et al (2000) developed a rehabilitator, "the leg Guide" (Assisted Rehabilitation and Measurement Guide). Their primary objectives in developing a rehabilitator were first, to provide an improved diagnostic tool for assessing arm movement impairment after brain injury, and, second, to provide a therapeutic tool for exploring the effects of active assist therapy. The stroke rehabilitation program involves working with a team to guide a stroke patient. This usually includes physical and occupational therapists. The rehab team will likely recommend combining a variety of exercises and other techniques to help a patient’s leg recover. Two big goals of stroke rehab are to enhance muscle control and reduce spasticity. This is a constant contraction of muscles that can lead to pain and other problems. Stroke rehabilitation for patient’s leg includes passive movements or exercises that are movements done with the help of a therapist and more active exercises patients do with little or no assistance.
CHAPTER 3

METHODOLOGY

3.0 Introduction

In this chapter, the development and the methodology of how the full system works will be explained in details. In this chapter, the overview of all procedures and methods that will be used in this project will be briefed. The main aim of this project is to design and develop a portable home based rehabilitation device. It is also involve the design and development of the hardware and software of the device to get an accurate result. Hence we are planning to design this project through many phases and collection all data for all instruments used. In this project, there are four main phases being considered to achieve the objective of the project. The first phase is the project planning which is to verify the concept and plan of the project. Besides that the second phase is system design which is to prepare and design the hardware part. To add to that the third phase is the software design in order to design the software code and testing. Last but not least the integration test which is to integrate system design and software design. These four phases can be simply summarized in the figure below.
Figure 3.1: Four main phases of the project.

3.1 Project Planning

Project planning is a very essential aspect in order to manage any project. In order to create a successful project, you need to have a great and clear plan for that project. Hence in this phase, we need to determine the concept of this project, following that the objectives and expected results can be developed. From these objectives, we identify the task that we need to fulfill our determined concept. Furthermore, to get more past and current ideas related to the concept we refer to literature review which will provide information in order to verify whether the proposed project is achieved or not. The flow chart shown in figure 3.2 explains the planning and implementation of this project which will be discussed in detail in this chapter.


Olsen, Tom Skyhøj. "Arm and leg paresis as outcome predictors in stroke rehabilitation.

