DESIGN AND IMPLEMENTATION OF HUMAN REHABILITATION INNOVATION FOR POST-STROKE PATIENTS

Arnon Nontapha

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By	Arnon Nontapha
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Thesis Advisor	Asst. Prof. Dr. Wimol San-Um

The Graduate School of Thai-Nichi Institute of Technology has been approved and accepted as partial fulfillment of the requirement for the Master's Degree

……………………………………….. Dean of the Graduate School
(Assoc. Prof. Dr. Pichit Sukcharoenpong)
Month……… Date……… Year………….

Thesis Committees

……………………………………….. Chairperson
(Dr. Apirath Limmanee)

……………………………………….. Committee
(Asst. Prof. Dr. Wipawadee Wongsuwan)

……………………………………….. Committee
(Dr. Kanticha Kittipeerachon)

……………………………………….. Advisor
(Asst. Prof.Dr. Wimol San-Um)

ARNON NONTAPHA : DESIGN AND IMPLEMENTATION OF HUMAN REHABILITATION INNOVATION FOR POST-STROKE PATIEN. ADVISOR : ASST. PROF. DR. WIMOL SAN-UM, 61 PP.

In regards to the prediction of Thai Stroke Society (TSS), it has been reported that the number of stroke patients will be approximately 200,000 people, and died over 28,000 people, especially elderly people. However, Thailand really lacks of the physical therapists for stroke therapies as well as rehabilitation devices which are very expensive. This thesis therefore aims to the first, present a unique design of a hand grip which is compatible to concise for post stroke patients. Most rehabilitation robots have focused on mechanics of robot body and grip stick, but this work alternatively focuses on the design of a new stable gripper as a robot end, which provides full function for training of arm and hand muscles. The design covers a controllable hand stick, a hand ball, and a curvature part for complete exercise. And the second, to present the experimental design and calibration of FlexiForce sensors for HandGlove force measurement utilizes for post-stroke patients. These sensors are a resistive force based technology which has force range of (0-445 N). In order to analyse the correlation between the output voltage and force applied to each sensor. In addition, Microcontroller, Arduino Uno model is applied to read output voltage from the sensor that is plugged into the output pin directly. The output force displays via LED screen. In addition, a power supply unit and operational amplifier (op-amp) module are used for scaling up the output signal according to a relationship between input and output signal. The evaluation of the sensor's accuracy is based on repeatability that presents the validity and reliability of the sensor. From the experimental results, the sensor repeatability is ± 2.99%that is slightly higher than the standard value of FlexiForce A201 (100 lbs).

Graduate School	Student's Signature………………………
Field of Study Engineering Technology	Advisor's Signature………………………
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Arnon Nontapha

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Chapter 1
Introduction

1.1 Introduction

This chapter presents the background of a research approach, the need for stroke patient rehabilitation, the need for arm rehabilitation for post-stroke patients. Alternative solution with rehabilitation robot and hand force measurement will also be described.

1.2 Background

Currently, Thailand is facing with increasing of the stroke patients over 200,000 people annually, and died over 28,000 people. Most stroke patients have an effect to motion functional movement, which results in serious disability, and directly affects for Activate of Daily Living (ADLs) such as eating bathing or dressing.

Rehabilitation for improving motion functional movements for post-stroke patients is relatively important for ADLs in practice. However, Thailand is lack of both physical therapists and rehabilitation robots for stroke therapy. Researchers have been focusing on using robot rehabilitation devices with particular features such as capability to the repetitive movement, the programmable resistance, the objective to evaluation and to measure the patient’s progress, and the sensing movement which able to assist the stroke patients to improve the motion functional movement that is closely the physical therapists’ assistance.

1.3 Motivation

As previously described in the situation of immensely stroke patients in Thailand, researcher foresees and aware to this problem. This is due to the researcher has an experience in an internship on muscle rehabilitation course at the department of orthopedic surgery and rehabilitation, faculty of medicine, Siriraj Hospital. Therefore, the Design and Implement of Human Rehabilitation Innovation for Post-Stroke Patients is an inspiration for this research topic.

1.4 Statement of Problems

Due to the insufficient physical therapists for stroke patients and the imported rehabilitation devices are too expensive to distribute for every Thai hospital. Based on these problems, the development of the rehabilitation device has therefore become the research topic of this thesis.

1.5 Objectives

1. To design of hand grip which covers training arm muscles movement in order to regain motion function of the post-stroke patients.
2. To develop HandGlove force measurement device to measure the hand muscle strength of the post-stroke patients.

1.6 Scope of research

This thesis focuses on (1) the designs of multi-function hand grip which covers training arm muscles movement, (2) a development HandGlove force measurement device to measure the hand muscle strength of the post-stroke patients.

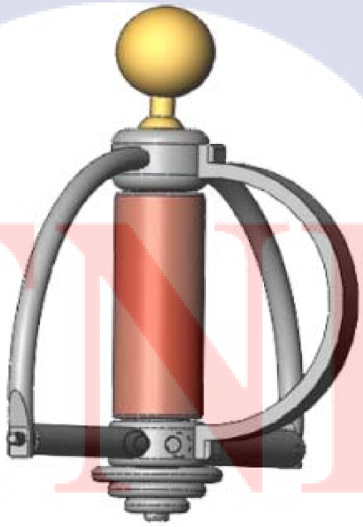


Figure 1.1 The pre-designed multi-functional hand grip.

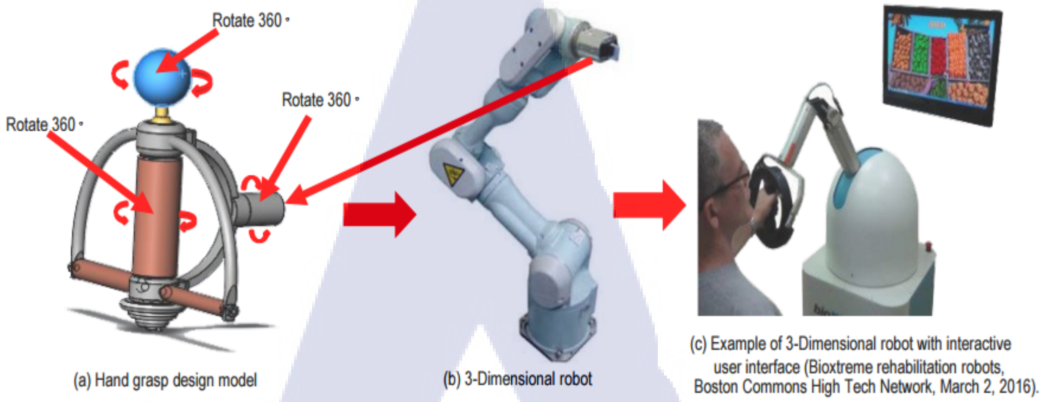


Figure 1.2 The overall scope of research with three stages.

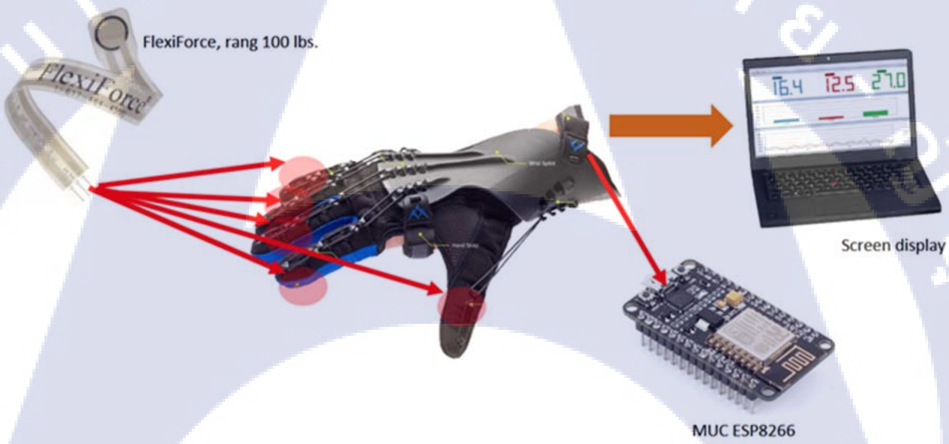


Figure 1.3 The pre-designed HandGlove force measurement.

1.7 Expected Outcomes

1. To achieve the hand grip design which covers training arm muscles movement in order to regain motion function of the post-stroke patients.
2. To achieve HandGlove force measurement device to measure hand muscle strength of the post-stroke patients.

1.8 Conclusions

This chapter has introduced the background therefore aims to the first, to designing of hand grip which covers training arm muscles movement in order to regain motion function of the post-stroke patients, and the second, to develop HandGlove force measurement device in order to measure the hand muscle strength of the post-stroke patients, statement of stroke problems that includes motivation of researchers. This chapter also summarized objectives as well as the expected outcomes of the research.

Chapter 2

Related Theories and Literature Reviews

2.1 Introduction

This part will introduce the related theories and literature reviews include commercial review which regarding the stroke patients and robotics rehabilitation include the literature reviews which regarding the Hand force measurement devices.

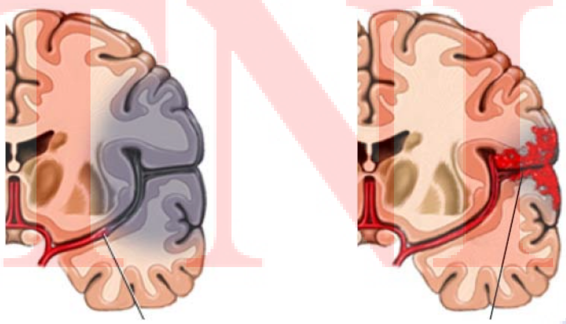
2.2 Related Theory

2.2.1 Stroke

Stroke (a cerebrovascular accident) occurs when there is an interruption of the blood supply to the brain. As blood is the carrier of nutrients to cells in the brain, a stroke occurs when cells are unable to maintain normal ion gradients due to a lack of oxygen. This leads to cell death [1]. Loss of blood can occur in two main ways.

2.2.1.1 Through a hemorrhagic stroke, where the blood vessels rupture and blood loss occurs.

2.2.1.2 Through an ischemic stroke, where there is blockage to the normal flow of blood to the brain, from a narrowed artery or from a blood clot that has broken off from another place.



(a) Ischemic Stroke (b) Hemorrhagic Stroke

Figure 2.1 A cerebrovascular accident.

When the motor, premotor cortex motor tracts, or associated pathways in the cerebrum or cerebellum are affected by stroke, the effect is motor impairment, which typically affects movement of the face, arm and leg of one side of the body. Motor impairment can have the effect of limiting a person's ability to achieve ADLs tasks.

There are a lot of risk factors associated with cardiovascular disease. Risk factors are largely categorized as controllable and uncontrollable factors. Controllable risk factors can be further classified as Medical and Lifestyle Risk Factors (as shown in Table 2.1). Despite a declining number of hospitalizations and deaths associated with stroke, it remains one of the most impactful of all chronic diseases. Diseases of the circulatory system are a leading cause of mortality and permanent adult disability. Stroke has a substantial impact on the Thais economy, families, and individuals.

Table 2.1 Stroke Risk Factors.

Uncontrollable Risk Factors	Controllable Risk Factors	
	Controllable Medical Risk Factors	Controllable Lifestyle Risk Factors
Age Gender Race Family History Previous Stroke or TIA Fibromuscular Dysplasia	High Blood Pressure Atrial Fibrillation High Cholesterol Diabetes Atherosclerosis Circulatory Problems	Tobacco Use and smoking Alcohol Use Physical Inactivity Obesity

2.2.2 Stroke recovery

There are at least three factors underlying stroke recovery: resolution of acute tissue damage, behavioral compensation, and brain plasticity. Much of the initial stage of spontaneous recovery is due to decrease in edema, hemorrhaging, and inflammation. Behavioral compensation occurs as stroke survivors develop compensational strategies to deal with their impairments. The third factor, brain plasticity, is the underlying basis for stroke exercises and rehabilitation.

After a cerebrovascular accident, the brain is able to regain its lost function through reallocating cell function. There are two factors: the brain having diffuse and redundant connections and its ability to form new structural and functional circuits through remapping. The brain is more plastic after stroke. Although cells do not reproduce, they are able to remodel, or change their structure and functionality with input from the environment. It has been shown that immediately after a stroke; this region is able to sprout new axons, creating new connections [2].

2.2.3 Implication for rehabilitation robotics Devices.

Rehabilitation Robotics Devices (RRDs) may be able to increase access to rehabilitation, especially during the immediately crucial period after stroke happened. For some stroke survivors, this perhaps mean to the difference between partial and full recovery of motor function. Outcomes of the affected limb are often dependent on its activity. As many stroke survivors would prefer to use their unaffected limb, the disuse of their affected limb can be detrimental to recovery.

Rehabilitation robots are able to offer an enriched environment even for minimally functioning limbs. Stroke survivors who have minimal usage of their affected limbs often are unable to participate in therapies. The more enriched the environment, the more senses involved. Robotic devices are able to repetitively move the arm, giving the brain sensory input over and over again. If there are other cues, which could be provided in a virtual reality environment, these could also strengthen neurological pathways for motor recovery. Just as mental imagery aids in strengthening the neural connections, imaging through a virtual environment does the same. The advantage of robot is it can combine a highly repeatable task (moving the limb) with feedback about performance, which provides the practice more. Repeated practice needs to have feedback of incremental success to give people motivation to continue. Virtual environments can do that in away real environments in the form of feedback and motivating activities and games. Virtual environments combined with a rehabilitation robot can provide repetitive movement, informative feedback, and motivating activities.

2.2.4 Force Sensors

A thin and flexible piezo-resistive Flexiforce sensor which can measure forces above 445 N (100 lbs.) were chosen for the HandGlove for Force Measurement. They were type A201 from Tekscan. The thickness, length, width and diameter of the sensing area of A201 are 0.203 mm, 191 mm, 14 mm and 9.53 mm respectively which is a polyester substrate. The resistance of A201 is at the level of MΩ when no load is applied. When a load is applied, it changes to the level of KΩ

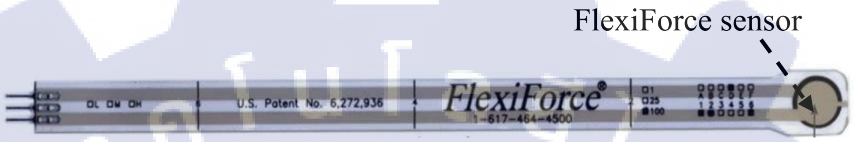


Figure 2.2 FlexiForce sensor.

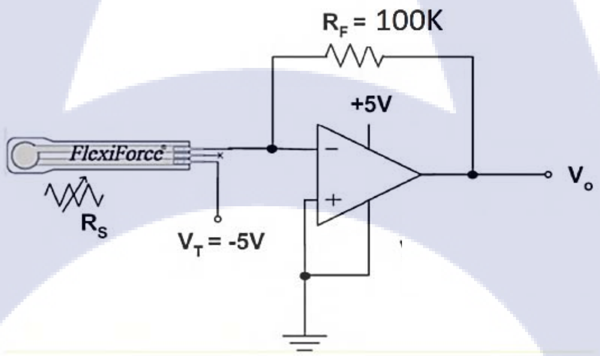


Figure 2.3 Measurement circuit of the Flexiforce sensor.

Table 2.2 Specification of the FlexiForce sensor A201[3].

Sensor Properties	Performance
Linearity (Error)	< ±3% of full scale (Line drawn from 0 to 50% load)
Repeatability (CoV)	< ±2.5% of full scale (conditioned sensor, 80% force applied)
Hysteresis	< 4.5 % of full scale (Conditioned sensor, 80% of full force applied)
Drift	<5% per logarithmic time scale (constant load of 90% sensor rating)
Response Time	< 5 microseconds (Impact load, output recorded on oscilloscope)
Operating Temperature	15°F to 140°F (-9°C to 60°C)

Table 2.2 Specification of the FlexiForce sensor A201 (Continued).

Sensor Properties	Performance
Output Change/Degree F	Up to 0.2% (~0.36% / °C). Loads <10 lbs, operating temperature can be increased to 165°F (74°C).
Sensor Resistance (RS)	No load is >5MΩ

2.2.5 The 3-Dimensional Robotics.

In the study of robotics which concerned with the location of objects in three-dimensional space. These objects are the links of the manipulator, the parts and tools with which it deals, and other objects in the manipulator's environment. At a crude but important level, these objects are described by just two attributes such as position and orientation. Naturally, one topic of immediate interest is the manner in which represent these quantities and manipulate them mathematically. In order to describe the position and orientation of a body in space, researcher attach a coordinate system, or frame, rigidly to the object. Researcher then proceed to describe the position and orientation of this frame with respect to some reference coordinate system. Any frame can serve as a reference system within which to express the position and orientation of a body, so we often think of transforming or changing the description of these attributes of a body from one frame to another [4].

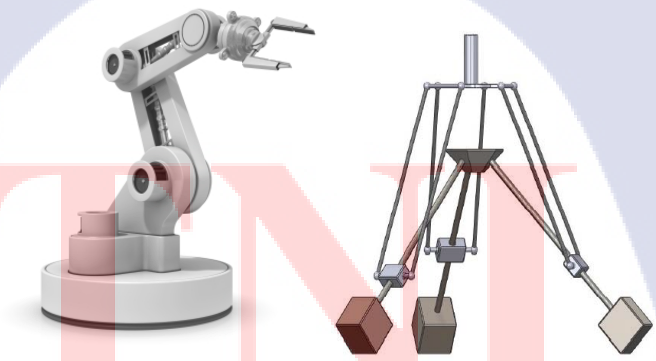


Figure 2.4 Auto assembles robot and robot delta.

2.2.6 Arduino Uno

The Arduino Uno is a microcontroller board based on the ATmega328. It has 20 digital input/output pins (of which 6 can be used as PWM outputs and 6 can be used as analog inputs), a 16 MHz resonator, a USB connection, a power jack, an in-circuit system programming (ICSP) header, and a reset button. It contains everything needed to support the microcontroller [5]. Microcontroller Arduino Uno model is applied to read the voltage value from the sensor that is plugged to the output pin directly into an Analog (ADC) input. A simply connect it to a computer (or appropriate wall power adapter) with a USB cable or power it with an AC-to-DC adapter or battery to get started.

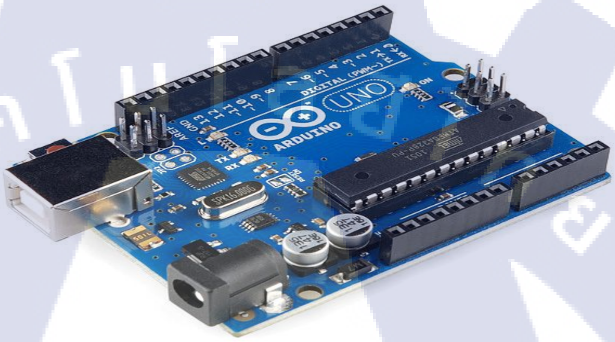
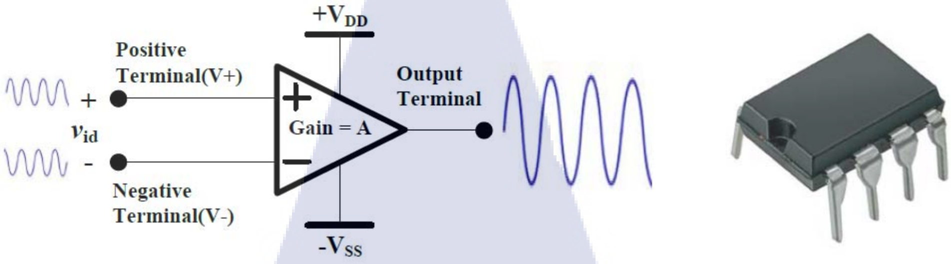


Figure 2.5 Arduino Uno broad.

2.2.7 Operational Amplifiers

An operational amplifier (op-amp) is a relation between input signal and output signal which almost uses for converting signal to bigger. The op-amp was intended for use with external feedback elements which determine the resultant function or operation, and hence the name “operational amplifier,” denoting that an amplifier can perform a variety of operations. There are two input terminals, i.e. non-inverting (V-) and inverting (V+) terminals, an output pin (Vo), and two power supply terminals (VDD, VSS) [6].



(a) (b)

Figure 2.6 (a) A standard Op-Amp symbol and (b) A commercial Op-Amp package.

The op-amp produces an output voltage that is typically hundreds of thousands of times larger than the voltage difference between its input terminals which is an important principle to get an accuracy value. Therefore, there are four factors to verify as following;

1. The current in circuit will always flow from high to low potential.
2. The output of circuit is detected by node calculation which is an easier principle.
3. The potential voltage at Op-Amp (Positive Terminal V+ and Positive Terminal V-) will always have the same value.
4. The Current is not always to flow into the Op-Amp module.

2.3 Literature reviews and Commercial reviews

In order to better understand the features of current upper limb robotic rehabilitation devices, a literature search was done on Google Scholar, and Medline. The search terms that limited articles concerning stroke were; “cerebrovascular accident”, “cerebrovascular disease”, and “stroke”. The search was then narrowed again to articles containing “upper limb”, “upper extremity”, or “arm”. Finally, the search was narrowed again to articles containing “robotic rehabilitation”. This paper will present both the upper-limb rehabilitation robots in the literature reviews and the robotic devices for rehabilitation which are commercial on the market.

2.3.1 Related literature reviews

Table 2.3 the summarizes research on the design robotic for rehabilitation for stroke therapy and commercial products, which are initially reviewed as purpose to design hand grip and to design rehabilitation robot include Table 2.4 the summarize research on the Hand Force Measurement for stroke patients. Two mainly linked the design of hand grip for rehabilitation robot with interactive user and the Finger Force Measurement device has previously been proposed.

Table 2.3 Research on the rehabilitation robotics device.

Year	Authors	Proposed schemes
2014	W. Kaewboon.	Arm Rehabilitation
2014	R. Morales et al.	Patient-Tailored Assistance: A New Concept of Assistive Robotic Device That Adapts to Individual Users
2014	Z. Song et al.	Implementation of Resistance Training Using an Upper-Limb Exoskeleton rehabilitation device for Elbow Joint
2013	A. Rahman and A. A. Jumaily.	Design and Development of a Bilateral Therapeutic Hand Device for Stroke Rehabilitation
2012	I. Galiana et al.	Wearable Soft Robotic Device for Post-Stroke Shoulder Rehabilitation: Identifying Misalignments
2008	E. T. Wolbrecht et al.	Optimizing Compliant, Model-Based Robotic Assistance to Promote Neurorehabilitation.
2007	R. C.V. Loureiro and W. S. Harwin.	Design and Control of a 9-DOF Robotic Neuro-rehabilitation System

W. Kaewboon [7] the study is a Thais student, factory of Electrical Engineering, Songkhla University, proposed the design for arm rehabilitation to regain movement for triceps and infraspinatus muscles. This study has used the

Electromyography (EMG) signal to measure and to evaluate muscle progression in order to analyze root mean square (RMS) and mean absolute value (MAV), and has used LabVIEW program to control both continuous passive motion (CPM) and Direct Exercise. The proposed system described that the system can be set velocity such as 5, 10, and 15 rounds per minute and mass such as 1 to 6 kgs. for training. The result of testing device showed the device can maintain velocity and function correctly with patient. Moreover, the result displayed that (RMS) and MAV of the EMG signals are increased when force level increased for both triceps and infraspinatus muscle.

(a) triceps training (b) infraspinatus training

Figure 2.7 The development of arm rehabilitation (a) triceps training (b) infraspinatus Training

R. Morales et al [8] presented the overview of the developing a new Concept for multimodal assistive robot that can assist the stroke patients as needed named "Patient-Tailored Assistance" that composed of a 7 DoF for safe human-robot interaction. The proposed had considered the patients residual physical and cognitive of physical abilities include developing to increase both the cognition and physical ability in activities of daily living (ADLs), such as drinking, cooking, eating, personal hygiene, and grooming. Moreover, the patient-tailored assistance robot can be adapted to each patient's individual characteristics and it can be used for reaching task for rehabilitation purpose. The main components of this assistive robotic device, as shown in Figure 2-5, are: 1) a multimodal HRI, including speech recognition and audio-visual feedback, a physiological monitoring system, and a biomechanical monitoring system and 2) an anthropomorphic robot arm in tight physical contact with user.

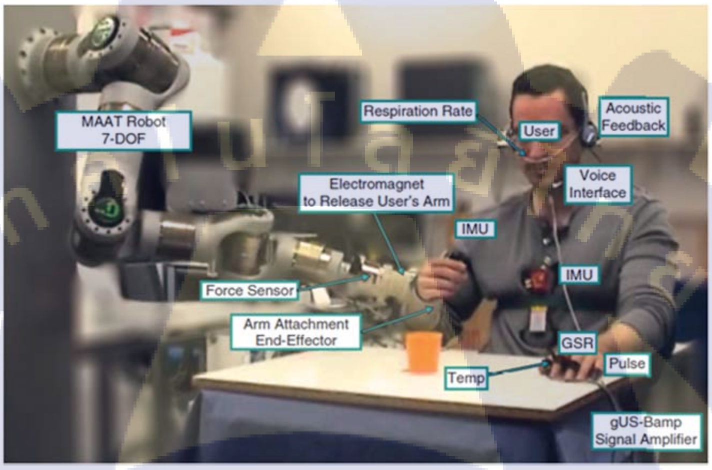


Figure 2.8 A multimodal assistive robotic platform.

Z. Song et al [9] presented upper-limb exoskeleton rehabilitation device which was a human-machine interactive HMI method which focused in assistance and passive training. Experimented was, passive DoF both lock and unlock elbow joint and used EMG to verify and evaluate the muscle processes at biceps and triceps muscle. This device focused to design resistance and passive training as a rehabilitation device that is suitable for severe impairments and some muscle strength. This device is consisted the EMG to measure progression of muscle at biceps and triceps muscle, inertial Sensor used to detect position, velocity, and acceleration include using the impedance control and admittance Control.

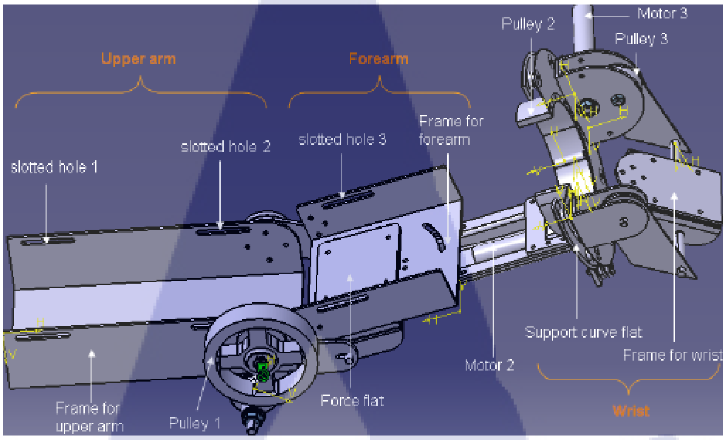
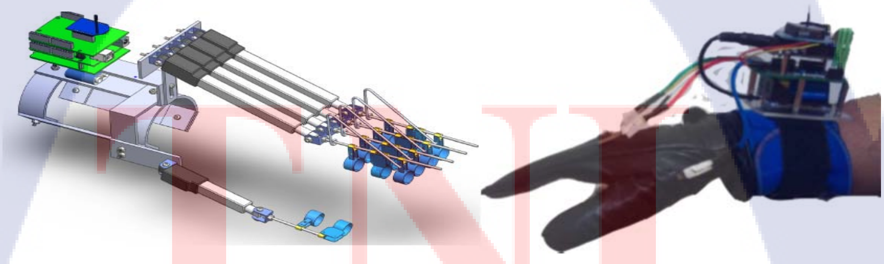


Figure 2.9 Upper-Limb Exoskeleton rehabilitation device for Elbow Joint.

A. Rhaman and A. A. Jumaily [10] proposed the Exoskeleton Rehabilitation device that is the bilateral movement training which can assist stroke patients to flex/extend each digits of the impaired hand compares the movement with the healthy hand. This device can assist 15 DoF of finger. This device cannot be training Ab/Ad movement of finger. This device cannot measure the performance or the progress of muscle regain. Generally, will use the EMG to detect the muscular progression. This device is a lightweight and can portable to use at home.



(a) design of the hand exoskeleton (b) the control glove

Figure 2.10 Bilateral Therapeutic Hand Device (a) the design of hand exoskeleton (b) the control glove.

I. Galiana et al [11] this group of study proposed the design and experimental validation of an adaptive, soft, wearable shoulder rehabilitation device aimed at providing assistive forces in the shoulder abduction-adduction DoF which provided the device structure and determine the kinematic degrees of freedom. The proposed device was robust to misalignments that may occur during actuation of the compliant brace or when putting on the system that used inertial measurement unit sensor (IMUs) to measure the force in liner include using piezoelectric to measure the angle of the device. The device was consisted by two cable that insert in soft Orthotic device are, Actuation cable to assist force in the abduction and adduction and Bowden flexible cable use to improve support the user and portability the system.

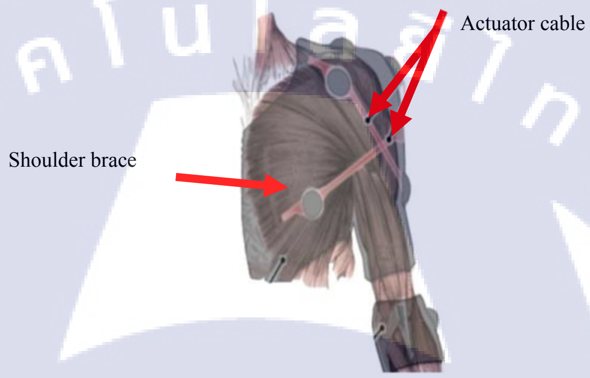


Figure 2.11 Wearable Soft Robotic Device.

E. T. Wolbrecht et al [12] presented a new controller to adaptive control law approach in order to learn the patient's abilities and assist in completing movements while remaining compliant namely assistance-as-needed. The experiment was conducted using the upper extremity robotic therapy device named "Pneu-WREX" (which is a 4 DoF robot based on a passive arm support) to evaluate the performance of the adaptive with people who have suffered a stroke and described the adaptive controller using a radial–basis function to assist patients in moving by Lyapunov based algorithm contains terms for both dynamics and force dynamics of the pneumatic actuators. The result of adaptive controller is capable of compliantly assisting patients with a force tailored to their impairment level. Adapted in real-time, removing the need to change parameters from patient to patient or from therapy session to therapy session.

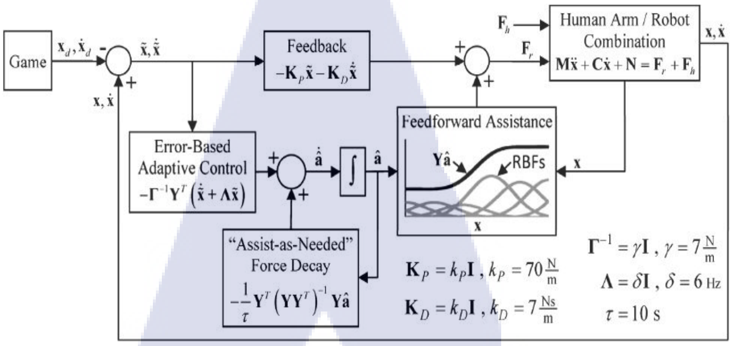


Figure 2.12 Controller diagram. The "assist-as-needed" force using radial basis function.

R. C.V. Loureiro and W. S. Harwin [13] presented the design the Gentle/G Robotic rehabilitation which was a human-machine interaction (HMI) that developed from Gentle/s Robot. The gentle/G Robot provided helping arm reaching movement to grasp and release the object. The Gentle/G Robot allowed for reaching movement in three active DoF as a haptic master which is a human connect to the grasp and 3 passive DoF which connects to mechanism. The Gentle/G Robot or a human-machine interface HMI used PC (Intel Pentium TV, 20H system running on window XP) to user interface and embedded real-time controller.

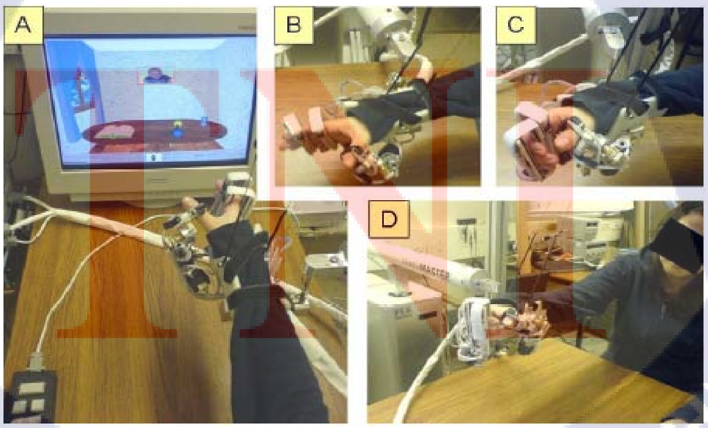


Figure 2.13 Design and Control of a 9-DOF Robotic Neuro-rehabilitation System.

Table 2.4 Research on the Finger Force Measurement.

Year	Authors	Proposed schemes
2016	O. Liska et al.	Design of active feedback for rehabilitation device
2016	Y. Zheng et al.	Development and evaluation of a sensor glove for hand functional assessment and preliminary attempts at assessing hand coordination
2015	A. Malik et al.	Development of smart glove system for therapy treatment.
2012	N. P. Oess et al.	Design and evaluation of a low-cost instrumented glove for hand function assessment
2012	S. K. Dixit and N. S. Shingi.	Implement of Flex sensor and Electronics Compass for Hand Gesture Based Wireless Automation of Material Handing Robot
2006	B.D. Lowea et al.	B.D. Lowea et al. Development and application of a hand force measurement system
2005	S. Olandersson et al.	Finger-Force Measurement-Device for Hand Rehabilitation

O. Liska et al [14] proposed the design of active feedback for rehabilitation device driven by pneumatic artificial muscles. The proposed system presented three methods to measure the load of robot. The first measurement of robot system is Force Sensitive Resistors (FSR) placed in the handle of device which measures the human touch. Two other methods are to measure the load of the actuator composed of artificial muscles. The principle of one method is to measure the difference filling pressures of the muscles and the second method measured the train in the drive cables or measuring the tensile forces by strain gauge.

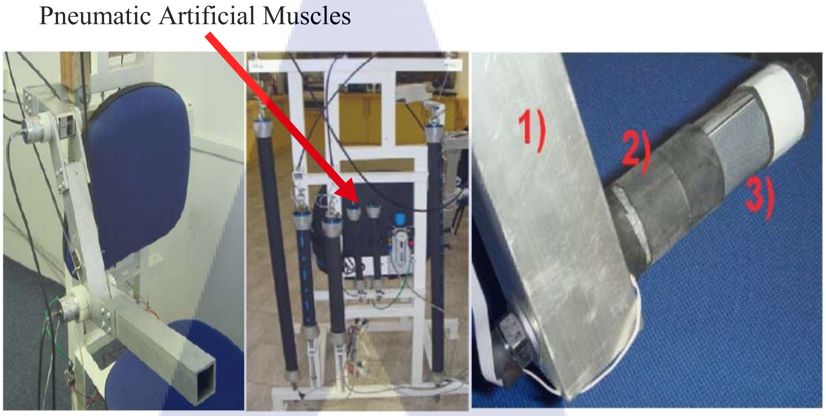


Figure 2.14 FSR sensors mounted on handle; 1) robot arm, 2) handle, 3) FSR sensor.

Y. Zheng et al [15] proposed the design of the sensor glove based on resistive bend sensor placed at dorsal finger and force sensor placed on the finger prominence in order to measure joint angle and force exertion of finger named FuncAssess Glove. The group of study has designed the experimental by embedded bend sensor to MCP, PIP, and IP of each fingers using voltage output signal to measure angle position as the validity evaluation of this experiment. At the same method using voltage output signal to measure force magnitude each size of weight condition to view the balance weight of finger.

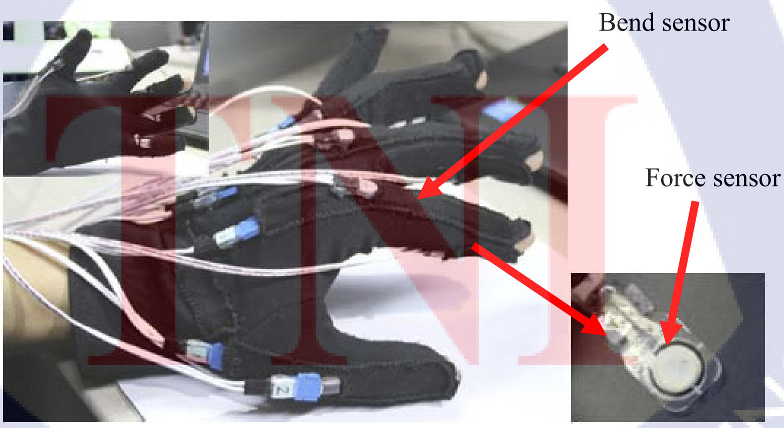


Figure 2.15 The design of sensor glove FuncAssess Glove.

A. Malik et al [16] proposed Four Flex sensors were assessed to implement as a sensory unit for a portable arm rehabilitation device (Smart Glove) to achieve finger bending or reflecting hand kinematics during the performance of ADL-based tasks. The analog signal from the sensors will be conveyed to an Arduino microcontroller for data processing and logging. The results of rehabilitation activity can be used for further monitoring and analysis.

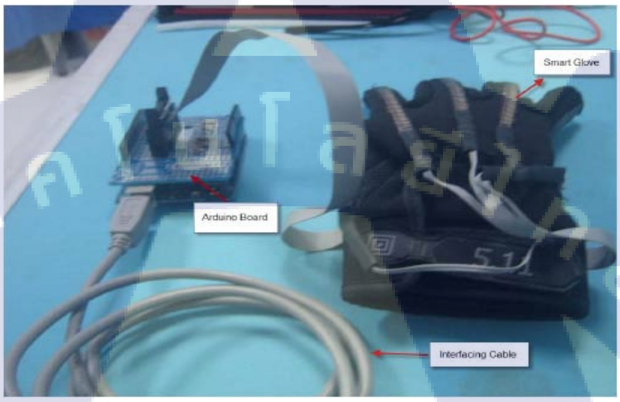
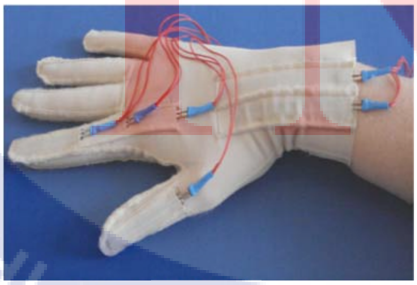
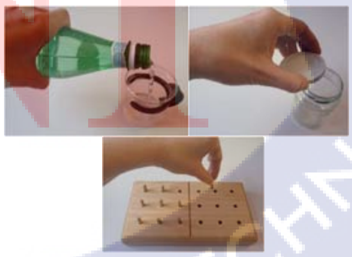


Figure 2.16 Implementation Four Flex sensors for Smart Glove.

N. P. Oess et al [17] proposed Design and evaluation of a low-cost instrumented glove for hand function assessment the evaluation of hand function impairment following a neurological disorder (stroke and cervical spinal cord injury). The proposed glove consists of 4 bend sensors with 2 different lengths were used. First, the short one of 2 sensors were used to monitor finger bending. Second, the longer one of 2 sensors were used to capture palmar and dorsal flexion of the wrist.



(a)



(b)

Figure 2.17 a) NeuroAssess Glove and b) Design NeuroAssess Glove testing with position grips.

S. K. Dixit and N. S. Shingi [18] proposed the Hand unit and Robotic unit which contains five mechanical fingers, movements of the fingers can be carried out using stepper motor or servo motor when operator carry out movement of hand using some flex sensors when the resistance of the sensors changes and this change is transmitted to robotic unit. Communication between flex sensor on operator finger (Hand Unit) and motor on mechanical finger (Robotic Unit) uses wireless communication namely ZigBee module or using GSM module.

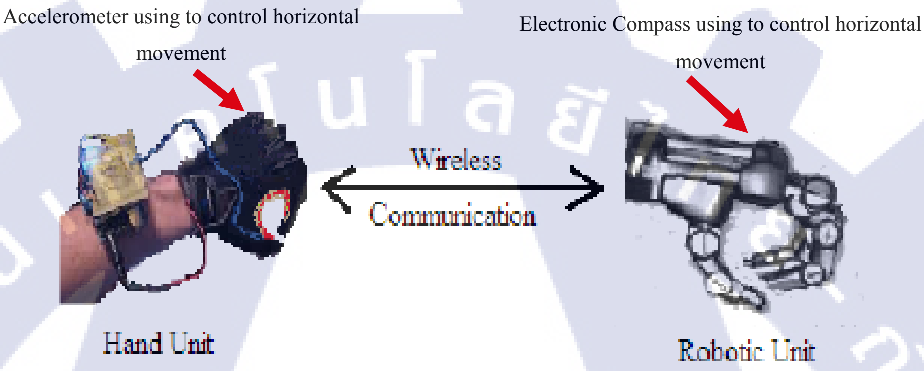


Figure 2.18 Implement of Flex sensor and Electronics Compass for Hand Gesture.

B.D. Lowea et al [19] proposed the development of a measurement system using the thin profile conductive polymer resistance-based force sensor attached to a glove of the contact force. This system used the linear regression to measure the error value between applied force and voltage output of the sensor. Typically, in the range of $0.986 < r2 < 0.995$. The system used high hand force exertion has been identified to be a risk factor for work related musculoskeletal disorders (WMSDs). Which magnitude of hand force exertion is concerning with awkward posture and repetitive motion which are associated with observable changes in the position and displacement of joint and limb segments is more difficult to assess visually.

Figure 2.19 Force sensor placement on the force glove of 20 mounted.

S. Olandersson et al [20] presented the development an extension finger-force measurement device which allows to measure single finger and whole hand. The repeatability error is used to measurement. This experiment showed that the repeatability error of less than 15 % can be achieved for single finger measurement and less than 21 % for whole hand measurements. The first experimental group has chosen to compare between healthy subject with patient with Rheumatoid Arthritis (RA) and the second experimental group have chosen the person who experienced with muscle symptoms such as weakness, pain, instability and deformities.

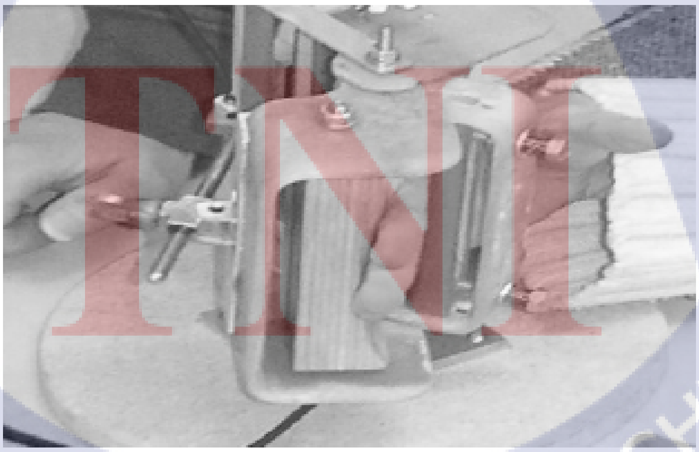


Figure 2.20 Finger-Force Measurement Devices for Hand Rehabilitation.

2.3.2 Commercial reviews

MIT-MANUS/InMotion2

Description

The most clinically studied upper limb robotic rehabilitation device is the MIT-Manus, or its commercial version, InMotion2 (Interactive Motion Technologies, Cambridge, MA). This robot has two degrees of freedom (DoF) and is an end-effector type of robot. The user's paretic forearm is placed in a supporting, which is attached to an end-effector. The user moves the handle in the transverse plane the robot focus on shoulder and elbow movement. A monitor displays user targets and provides visual feedback, the MIT-MANUS has developed over the years to include modular components that allow a one DoF vertical movement and a three DoF wrist movements. As well as a grasp sensor. The MIT-MANUS has three modes for the user: resisted, where the robot magnifies the user's actions in the direction the user is moving; and assisted movement, where the robot does all the moving and the paretic arm is passively moved. The MIT-MANUS is able to generate more or less assistance depending on the user's ability. The two DoF horizontal robot is portable (390 N) and has a back-drivable five bar-linkage SCARA (selective compliance assembly robot arm) mechanism, which is impedance controlled. The MIT-MANUS as an end-effector system only allows for movement detected at the hand. Horizontally, it has two DoF and vertically it has a separate on DoF [21].

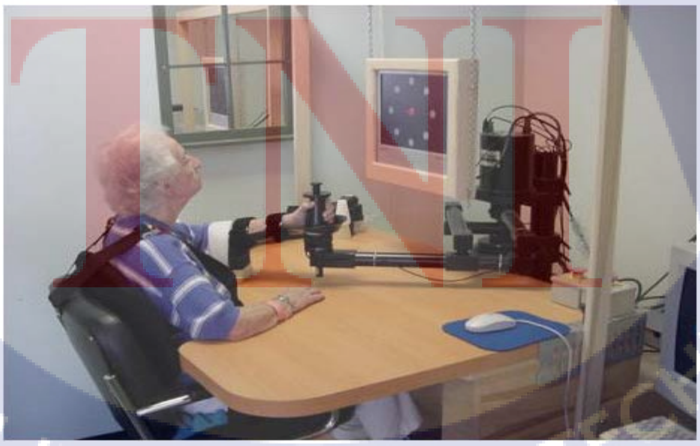


Figure 2.21 MIT-MANUS/InMotion2 Robot Rehabilitation.

NeReBot

Description

The Neuro-Rehabilitation-Robot called "NeReBot" is a 3 DoF wire-based robot. It supports the arm through cables attached to overhead arms which are attached to a transportable C-frame. This robotic system is powered by three direct current (DC) motors at the top of the device. The NeReBot transforms hand-over-hand therapy by learning movement from therapists and then repeating these movements with patients. The robotic system has visual feedback through a screen monitor. Therapists can set the angular and linear position as connect to the patients and for exercise which can help their reaching movement by pushing or pulling [22].

Figure 2.22 The NeReBot Rehabilitation.

ARMin (ArmeoPower)

Description

The ArmeoPower allows early rehabilitation of motor abilities and provides intelligent arm support in a large 3D space task. As a part of the sustainable ArmeoPower Therapy Concept, the ArmeoPower is designed for individuals who have suffered or severe with strokes, traumatic brain injuries or other neurological disorders resulting in hand and arm impairment. This device can able even patients with severe movement impairments to perform exercises with a high number of repetitions, which is helpful for regaining motor movement function [23].

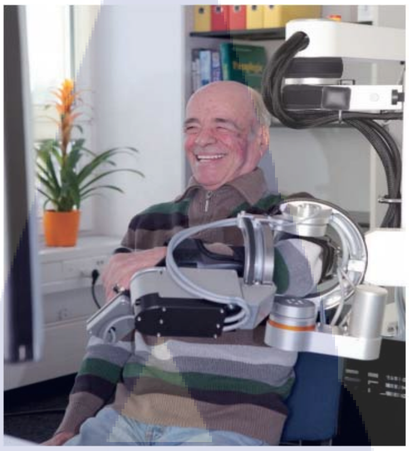


Figure 2.23 ARMin – ArmeoPower.

T-WREX (Armeo Spring)

Description

The T-WREX allowed harsh weakened patients to moveable which helped achieve tasks because this system allowed a large range of motion and had been explicitly designed to allow feeding and other functional movements. But also design and using a grip sensor which use to detect in hand grasp, to support people with weakened to practice using their hands in coordination with their arms. The system also developed new computer games that were easy to learn yet engaging and which approximated the movements needed for activities of daily living. These games included activities such as cooking, shopping, bathing, and cleaning [24].

Figure 2.24 The T-WREX Robotic Rehabilitation.

2.4 Conclusions

This chapter has presented the related theory particularly a key concept of stroke, robotic rehabilitation, Flexiforce sensor, operation amplifier and Arduino Uno. In addition, Literature reviews rehabilitation and commercial reviews on existing robotics rehabilitation for post stroke patients include Hand force measurement devices has also been included.

Chapter 3
Research Methodology

3.1 Introduction

This chapter presents the research methodology the design and implementation of human rehabilitation innovation for post-stroke patients. The five purposes of this chapter are to (1) describe the overall research processes of this research, (2) explain the data collecting and summarization, (3) describe the research tools used in designing the instrument and collecting the data, (4) describe the data analysis methods and (5) describe the research procedures.

3.2 Overall Research Processes

3.2.1 Reviewing relate research publication that focus on robotics rehabilitation and design the robotic device to regain motor movement for stroke patients. In addition, reviewing relate research publication that focus on force measurement device to measure the hand muscle strength of the post-stroke patients.

3.2.2 Study the arm anatomy includes arm movement.

3.2.3 Hand and anatomy include hand grasp position.

3.2.4 To develop Hand Glove force measurement device to measure the hand muscle strength of the post-stroke patients.

3.3 Data Collection

The data collecting in this research done by measuring and recording the output voltages by using the load cell placed on the sensor. The output signal was measured by multimeter. Voltage change will record the data using sensor for analysis and measuring the progression of muscle strength by using the FlexForce sensor and display sensor output via LED screen.

3.4 Research Tools

3.4.1 In this research, the entire of the Hand grips designing were designed through SolidWorks software and the entire of the HandGlve fore measurement programming were programed through Arduino Open source programming.

3.4.2 The FlexiForce sensor is used to analyze and to measure the muscle progression.

3.5 Conclusion

The purpose of this chapter was to describe the overall research processes of this research, explain the data collecting and summarization, describes the research tools used to Design and Implement of Human Rehabilitation Innovation.

Chapter 4
Experimental Results

4.1 Introduction

This chapter describes the research of versatility multi-function hand grip designed for hand muscle exercise and the experimental results of FlexiForce sensors calibration for HandGlove force measurement in order to measure hand muscles strength in Post-Stroke Patients.

4.2 Proposed Multi-function Hand Grip

Figures 4.1 shows the proposed 3-dimensional versatility multi-function hand grip design for rehabilitation robot, which can be used for six main functions. It can be seen the hand grip comprises a hand stick, a hand ball, and a curvature part for complete exercise.

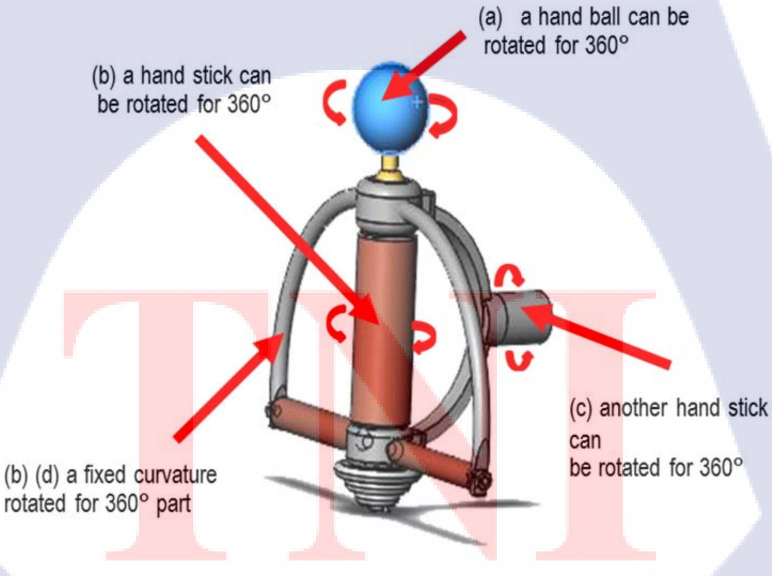
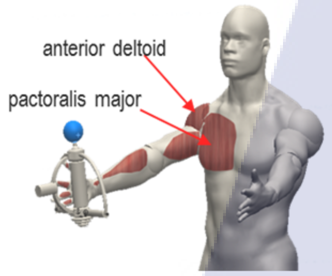
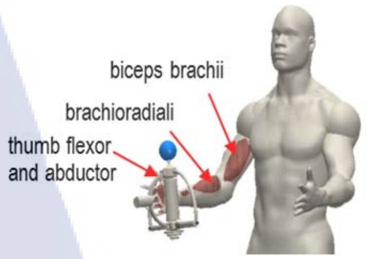


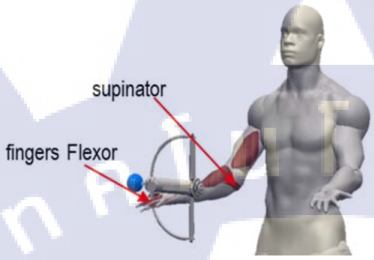
Figure 4.1 The proposed 3-dimensional versatility multi-function hand grip designed For rehabilitation robot.



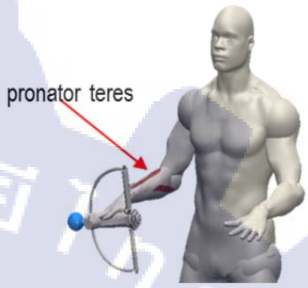
a) Rehabilitation for Pectorals major and anterior deltoid.



b) Rehabilitation for pronator teres.



c) Rehabilitation for finger flexor and supinator.



d) Rehabilitation for finger flexor and Biceps brachii.

Figure 4.2 The muscles are changed corresponding to Power grip when the hand grip model position is changed.

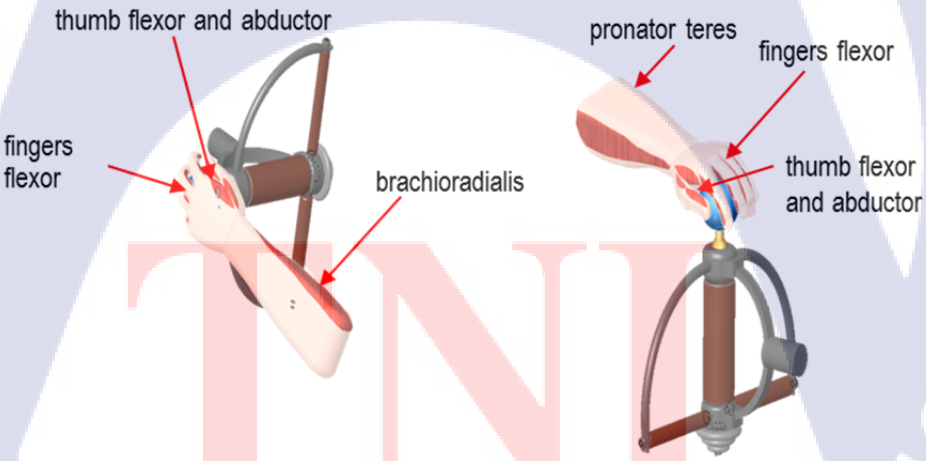


Figure 4.3 The muscles are changed corresponding to Spherical grip when the hand grip model position is changed.

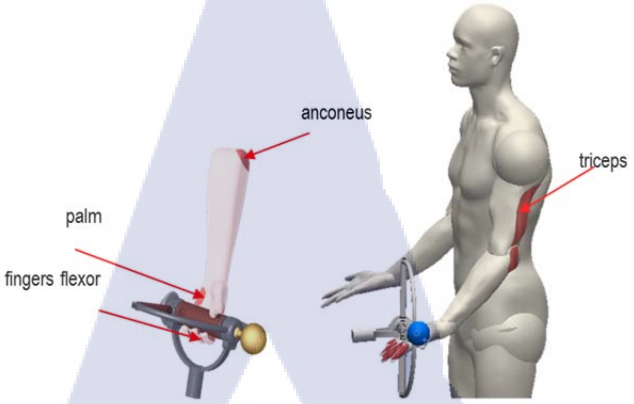


Figure 4.4 The muscles changed with Hook grip when the hand grip model position is changed.

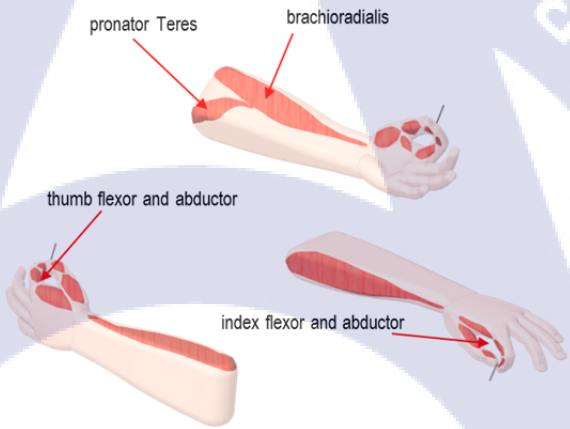


Figure 4.5 The muscles changed with Tip-to-tip grip when the hand grip model position is changed.

Figure 4.6 The muscles changed with Pad-to-side grip when the hand grip model position is changed.

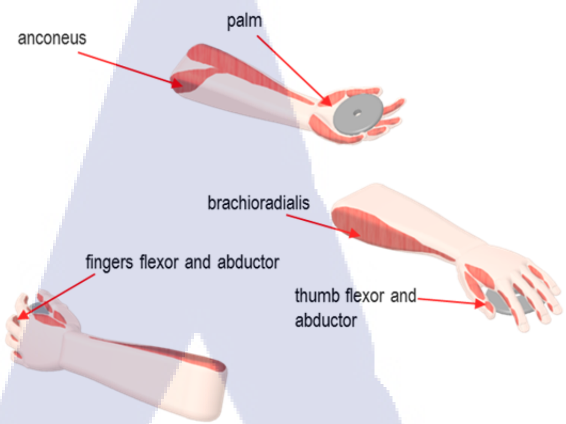


Figure 4.7 The muscles changed with Palmar grip when the hand grip model position is changed.

4.2.1 Physical Impacts of The Proposed Hand Grip Model

In this section, the 6 characteristics of hand grip model will be described in terms of physical impacts through an info-graphical illustration, involving power grip, hook grip, spherical grip, pad-to-side grip, palmer grip, and Tip-to-tip grip. Each function provides different muscle rehabilitation. Figure 4.2 illustrates rrehabilitation for hand and arm muscles using the proposed hand grip. It can be seen in Figure 4.2 that the proposed hand grip provides rehabilitation for Pectorals major and anterior deltoid, pronator teres, finger flexor and supinator, and also finger flexor and supinator. Figure 4.3 depicts the rehabilitation for fingers, hand and arm muscles using the proposed hand grip at the ball part. Additionally, Figure 4.4 shows the rehabilitation for fingers, hand and particularly triceps muscles. Moreover, the designed hand grip can also be also used for adding some small part for particular exercising of fingers, and, and arm of stroke patients. As mentioned earlier, Figures 4.5-4.7 illustrated the muscles are changed corresponding to tip-to-tip grip, pad-to-side grip, and palmer grip, respectively, when the hand grip model position is changed.

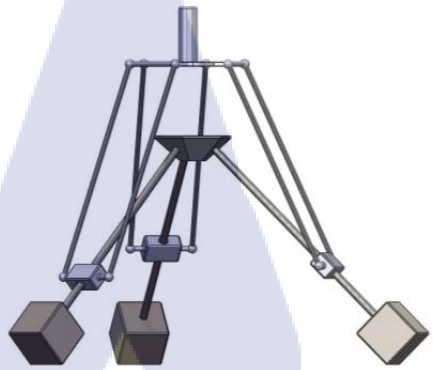


Figure 4.8 The 3-Dimensional model of the designed robot at normal position where the hand grip will be attached to the top of the robot legs.

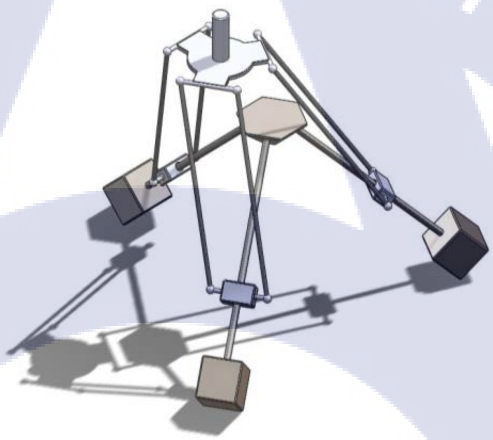


Figure 4.9 Another 3-dimensional model of the robot at bending position where the hand grip will also be attached to the top of the robot legs.

4.2.2 Discussions and Conclusions

In the part of designing of hand grip which covers training arm muscles movement in order to regain motion function of the post-stroke patients. This work has alternatively attempted to design a versatile hand grip which is compatible to concise arm and hand rehabilitation robot for stroke patients. The design covers a controllable hand stick, a hand ball, and a curvature part for complete exercise. Such a hand grip is capable of providing six main functions, involving power grip, hook grip, spherical grip, pad-to-side grip, palmer grip, and Tip-to-tip grip. Additionally, Figures

4.8-4.9 shows of designing of the 3-Dimensional model of the designed robot at normal position where the hand grip will be attached to the top of the robot legs that would be proposing in the future work.

4.3 Proposed HandGlove force measurement

4.3.1 Sensor Calibration

An ultra-thin and flexible piezo resistive printed circuit, which can be simply integrated into most applications. According to the thin structure, flexibility, as well as force measurement ability, the FlexiForce sensor can measure force in between most of surfaces. Moreover, it is durable enough to stand up to most environments. The sensor is not only durable but also linearity, hysteresis, drift, and temperature sensitivity than any other thin-film force sensors. FlexiForce sensor, which can measure forces above 445 N (100 lbs) were chosen for the HandGlove for Force Measurement. The FlexiForce sensor A201, which is made by Tekscan, are shown in Figure 2.2 The thickness, length, width and diameter of the sensing area of A201 are 0.203 mm, 191 mm, 14 mm and 9.53 mm respectively which is a polyester substrate. Specifications of the FlexiForce sensor A201 are shown in Table 2.2. The resistances of A201 are at the level of mega-ohm when there is no load. Nevertheless, the resistance can change into the level of kilo-ohm when the sensor is placed by the load cells. The accuracy of the sensor was evaluated based on repeatability, which will be described in detail in section 4.4.3. We set up the experiment by using the force sensor as a high stability sensor used in the HandGlove for force measurement.

In the experiment, the force sensors have been fixed on a flat at the front side up by using the load cell placed on the sensor and output voltages were measured respectively following the load cell values. These are 0.5 kg, 1 kg, 1.5 kg, 2 kg, 2.5 kg, 3 kg, 3.5 kg, 4 kg, 4.5 kg, and 5 kg respectively. The output signal was measured by Multimeter and the calibration set up is depicted in Figure 4.10.

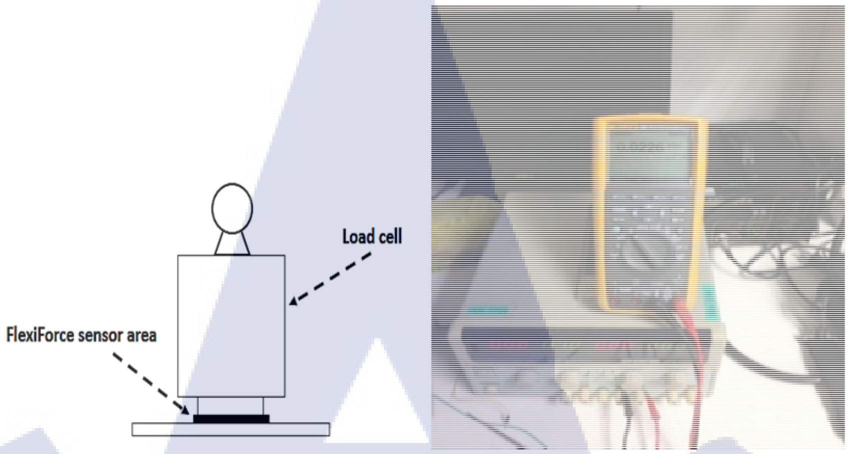


Figure 4.10 Investigation FlexiForce sensors with load cell and get voltage output by multimeter.

Table 4.1 The data of voltage output changed when applied load cells to sensor 1.

Load applied (lb)	Voltage output (VDC)						Average (VDC)
	Test 1	Test 2	Test 3	Test 4	Test 5	Test 6	
0	0.0202	0.0200	0.0205	0.0195	0.0200	0.0190	0.0199
1.1	0.1462	0.1360	0.1436	0.1347	0.1465	0.1526	0.1433
2.2	0.2659	0.2865	0.2671	0.2775	0.2698	0.2683	0.2725
2.3	0.4915	0.4589	0.4365	0.4558	0.4785	0.4815	0.4671
4.4	0.5821	0.5853	0.5723	0.6030	0.5901	0.5912	0.5873
5.5	0.7389	0.7360	0.7574	0.8558	0.7452	0.7623	0.7659
6.6	0.9785	0.9761	1.0052	0.9465	0.9470	0.9522	0.9676
7.7	1.1505	1.0594	1.0455	1.0874	1.0981	1.1135	1.0924
9.8	1.3875	1.4272	1.4665	1.3451	1.3751	1.4147	1.4027
9.9	1.6142	1.6403	1.6095	1.6315	1.7090	1.6254	1.6383
11	1.9574	1.8709	1.9274	1.9235	1.9319	2.0468	1.9430

Table 4.2 The data of voltage output changed when applied load cells to sensor 2.

Load applied (lb)	**Voltage output (VDC)**						**Average (VDC)**
	Test 1	**Test 2**	**Test 3**	**Test 4**	**Test 5**	**Test 6**	
0	0.0200	0.0205	0.0195	0.0200	0.0195	0.0200	0.0199
1.1	0.1522	0.1524	0.1696	0.1550	0.1500	0.1534	0.1554
2.2	0.3275	0.3023	0.2895	0.3513	0.3212	0.3253	0.3195
2.3	0.5231	0.5359	0.4905	0.4937	0.5154	0.5270	0.5143
4.4	0.6339	0.6705	0.6420	0.6611	0.6824	0.6354	0.6542
5.5	0.7864	0.7772	0.7228	0.7558	0.7741	0.7605	0.7628
6.6	1.0215	1.1075	1.0273	1.0742	1.0053	0.9846	1.0367
7.7	1.2283	1.3190	1.3681	1.2997	1.3268	1.3149	1.3095
9.8	1.5827	1.6917	1.5887	1.5598	1.6250	1.5635	1.6019
9.9	1.7071	1.6392	1.6545	1.7423	1.7338	1.7228	1.7000
11	1.8249	2.0157	1.9703	1.9704	1.9595	1.9563	1.9495

Table 4.3 The data of voltage output changed when applied load cells to sensor 3.

Load applied (lb)	**Voltage output (VDC)**						**Average (VDC)**
	Test 1	**Test 2**	**Test 3**	**Test 4**	**Test 5**	**Test 6**	
0	0.0195	0.0202	0.0207	0.0195	0.0200	0.0205	0.0201
1.1	0.1209	0.1184	0.1204	0.1241	0.1143	0.1253	0.1206
2.2	0.2562	0.3042	0.2508	0.2170	0.2043	0.2272	0.2433
2.3	0.3981	0.4317	0.3875	0.3362	0.3898	0.3690	0.3854
4.4	0.5604	0.5445	0.5945	0.5582	0.6650	0.5532	0.5793
5.5	0.7471	0.7642	0.7645	0.8550	0.8083	0.8635	0.8004
6.6	0.9047	1.0513	1.1365	1.0653	0.9556	0.9505	1.0107
7.7	1.2175	1.0535	1.1079	1.1283	1.1675	1.2863	1.1602
9.8	1.4505	1.4308	1.4345	1.2803	1.4783	1.2586	1.3888
9.9	1.5783	1.5078	1.6207	1.6978	1.7502	1.7548	1.6516
11	1.7261	1.9503	1.9097	1.8564	1.9162	1.8084	1.8612

The output voltage, which is produced by the force sensor, is then passed through an instrumentation operational amplifier (op-amp), MC6004 module which is used for converting signal to scale up the output signal which is a relation between input signals. A standard connection of the FlexiForc sensor's circuit with op-amp-MCP6004, reference resistance and FlexiForce sensor (Adjustable sensor resistance). Figure 4.11 shows the dynamic force range of the sensor can be adjusted by changing the reference resistor (Rf) or by changing the output voltage (Vo). The output voltage was obtained by using the load cells placed on the front side of the FlexiForce sensor. Whereas, the reference resistance is (Rf) and the sensor resistance is (Rs) can be calculated by equation (1).

$$Vout = -\frac{Rf}{Rs}.Vin \qquad (1)$$

When

Rf is the reference resistance of 100 K-Ohms.

Rs is the sensor resistance.

V_{in} is the voltage input of 5 V.

V_{out} is the voltage output.

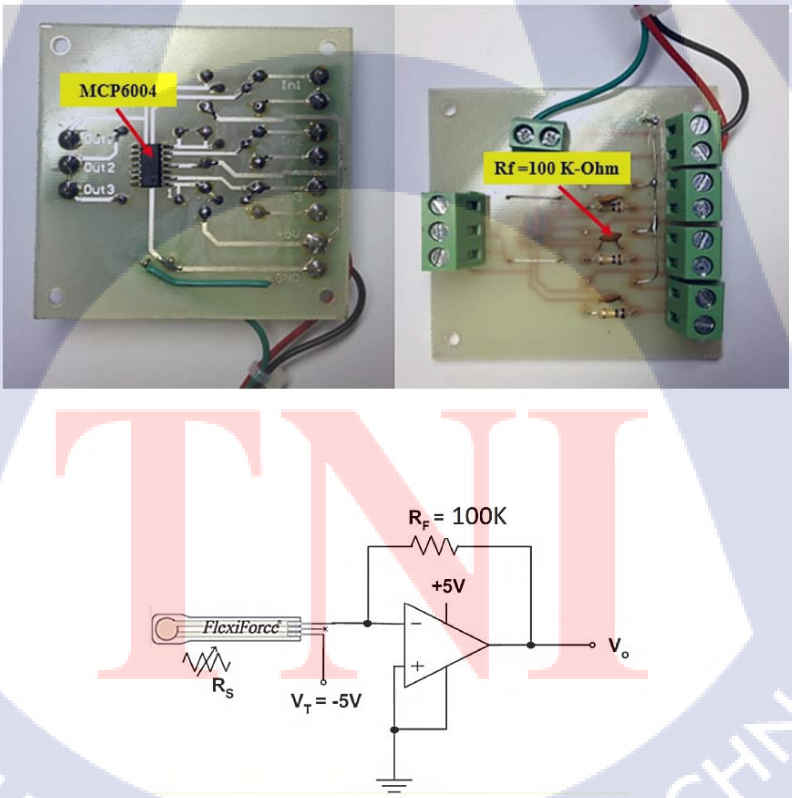


Figure 4.11 Measurement circuit for sensor calibration.

Table 4.4 The data of resistance is obtained from experimental results.

Load applied (lb)	Resistance (K-Ohms)		
	Sensor 1	Sensor 2	Sensor 3
0	24752.4752	25000.0000	25641.0256
1.1	3489.9953	3216.8132	4147.0832
2.2	1834.7502	1564.8636	2055.2168
3.3	1070.3964	972.2582	1297.4095
4.4	851.3053	764.2728	863.1107
5.5	652.7983	655.4798	624.6616
6.6	516.7514	482.2841	494.7311
7.7	457.7078	381.8348	430.9726
8.8	356.4596	312.1293	360.0144
9.9	305.1913	294.1263	302.7367
11	257.3362	256.4738	268.6463

Table 4.5 The data of conductance (1/R) is obtained from experimental results.

Load applied (lb)	Conductance (K-Ohms)		
	Sensor 1	Sensor 2	Sensor 3
0	0.0000	0.0000	0.0000
1.1	0.0003	0.0003	0.0002
2.2	0.0005	0.0006	0.0005
3.3	0.0009	0.0010	0.0008
4.4	0.0012	0.0013	0.0012
5.5	0.0015	0.0015	0.0016
6.6	0.0019	0.0021	0.0020
7.7	0.0022	0.0026	0.0023
8.8	0.0028	0.0032	0.0028
9.9	0.0033	0.0034	0.0033
11	0.0039	0.0039	0.0037

4.3.2 Prototyping and Software Implementation

A controller tool kit, Arduino Uno is a microcontroller board based on the ATmega328. It has 20 digital input/output pins (of which 6 can be used as PWM outputs and 6 can be used as analog inputs), a 16 MHz resonator, a USB connection, a power jack, an in-circuit system programming (ICSP) header, and a reset button. It contains everything needed to support the microcontroller. Microcontroller Arduino Uno model is applied to read the voltage value from the sensor that is plugged to the output pin directly into an Analog (ADC) input. A simply connect it to a LED screen (or appropriate wall power adapter) with a USB cable or power it with a AC-to-DC adapter or battery to get started are shown in Figure 4.13. The schematic circuit for two force sensors and the connection of their peripheral components are shown in Figure 4.12.

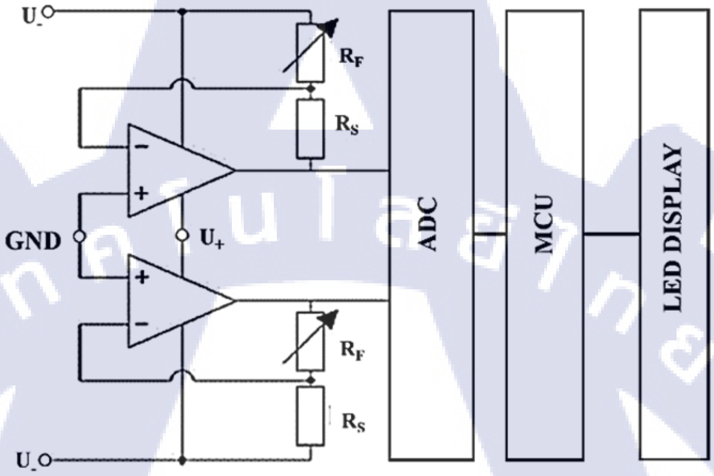


Figure 4.12 Schematic circuits for HandGlove force measurement.

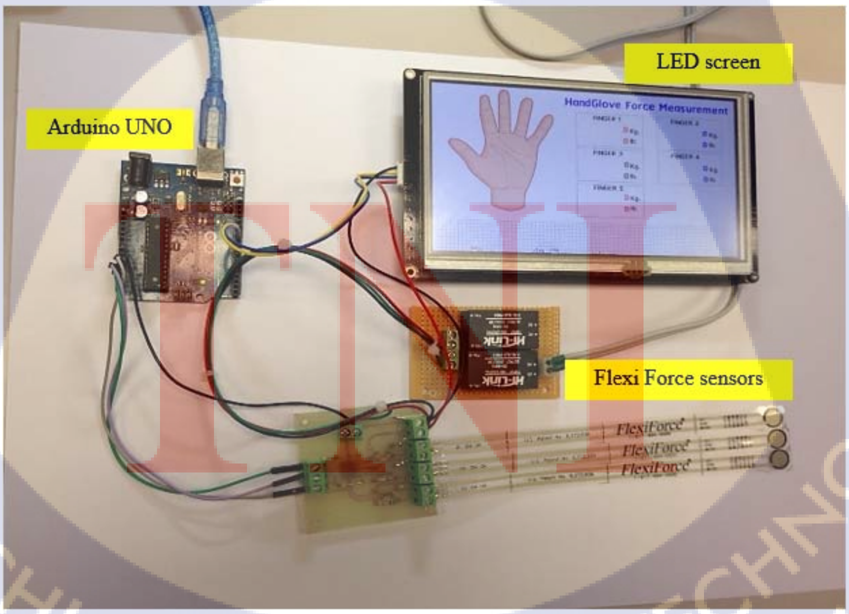


Figure 4.13 The development of the HandGlove force management utilize with three FlexiForce sensors.

4.3.3 Evaluation of FlexiForce Sensor

Calibration, the method by which the sensor's electrical output is related to an actual engineering unit, such as pounds or Newtons. To calibrate, apply a known force to the sensor, and equate the sensor resistance output to this force. The weights are used in this experiment varying from 0.5 to 5.0 Kg. Repeat this step with a number of known forces that approximate the load range to be used in testing. In this paper, the number of repeating is 6-time.

The Sensor validity and reliability is evaluated by repeatability, which refers to the ability of the sensor to respond in the same way when there is a number of repeated applications by using the same input (applied force). As with most measurement devices, it is customary to exercise, or "condition" a sensor before calibrating it or using it for measurement. This is done to reduce the amount of change in the sensor response due to repeated loading and unloading. A sensor is conditioned by loading it to 110 % of the test weight four or five times.

Considering to the output, which can be obtained from the three conditions. In addition, the standard deviation of the output should be less than the first and second conditions. Repeatable sensors are very important to produce reliable results. In the experiments, The FlexiForce A201 was loaded with a load cell 5 kgs (49.03 N), in several times. Repeatability can be calculated via;

$$repeatability = \frac{SDRs}{AverageRs} x100 \qquad (2)$$

4.3.4 Discussion and Results

A linear interpolation can then be done between zero load and the known calibration loads (0-5.0 Kg), to determine the actual force range that matches the sensor output range. Plot Force versus Resistance and Conductance (1/R) referring to the FlexiForce datasheet are shown in Figure 4.14 and 4.16 respectively. The experimental results of the plotting between force and resistance, as well as, conductance are shown in Figure 4.15 and 4.17 from the figures. The graph shape is quite close to figures in the datasheet. Due to the number of times for the experiments is quite few, the graph shape is not as smooth as the referred graphs.

Similar to the repeatability result, which is ± 2.99% is slightly higher than the standard repeatability value of ± 2.5 %, FlexiForce A201 (100 lb) datasheet. Due to the fact that there are only 6 tests were performed. Therefore, in order to obtain a more accurate repeatability values, the number of repeatability test should be increased and performed on different times and days with the same measurement setup, conditions and parameters.

Table 4.6 The average voltage output when applied load cells.

Load applied (kg)	Load applied (lb)	Sensor 1 (VDC)	Sensor 2 (VDC)	Sensor 3 (VDC)
0	0	0.0000	0.0000	0.0000
0.5	1.1	0.0003	0.0003	0.0002
1	2.2	0.0005	0.0006	0.0005
1.5	3.3	0.0009	0.0010	0.0008
2	4.4	0.0012	0.0013	0.0012
2.5	5.5	0.0015	0.0015	0.0016
3	6.6	0.0019	0.0021	0.0020
3.5	7.7	0.0022	0.0026	0.0023
4	8.8	0.0028	0.0032	0.0028
4.5	9.9	0.0033	0.0034	0.0033
5	11	0.0039	0.0039	0.0037

Table 4.7 The average resistance changed when applied load cells.

Load applied (kg)	Load applied (lb)	Sensor 1 (K-Ohms)	Sensor 2 (K-Ohms)	Sensor 3 (K-Ohms)
0	0	24752.4752	25000.0000	25641.0256
0.5	1.1	3489.9953	3216.8132	4147.0832
1	2.2	1834.7502	1564.8636	2055.2168
1.5	3.3	1070.3964	972.2582	1297.4095
2	4.4	851.3053	764.2728	863.1107
2.5	5.5	652.7983	655.4798	624.6616
3	6.6	516.7514	482.2841	494.7311
3.5	7.7	457.7078	381.8348	430.9726
4	8.8	356.4596	312.1293	360.0144
4.5	9.9	305.1913	294.1263	302.7367
5	11	257.3362	256.4738	268.6463

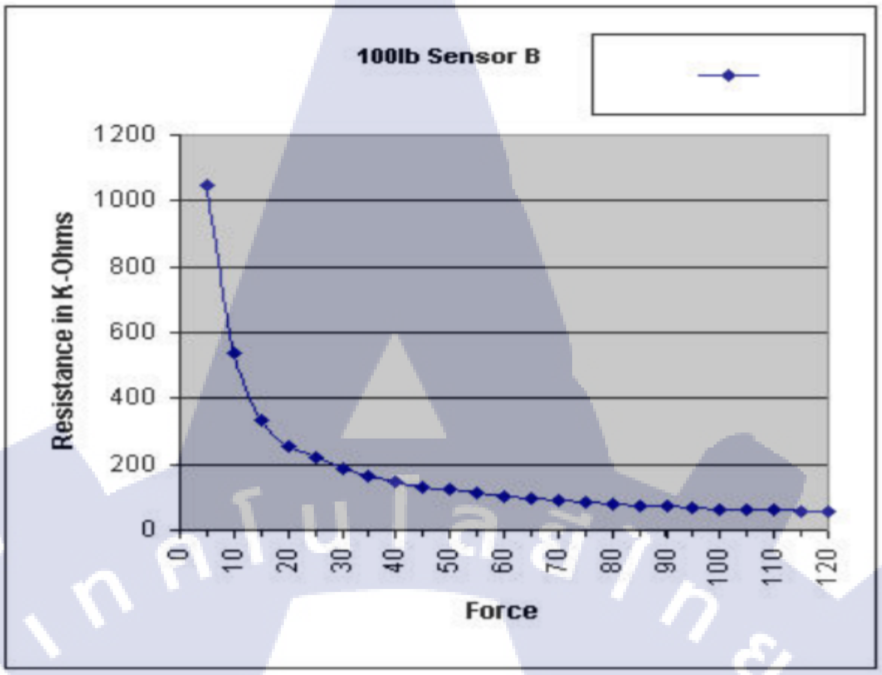


Figure 4.14 The relationship between applied force and resistance is obtained from FlixiForce datasheet.

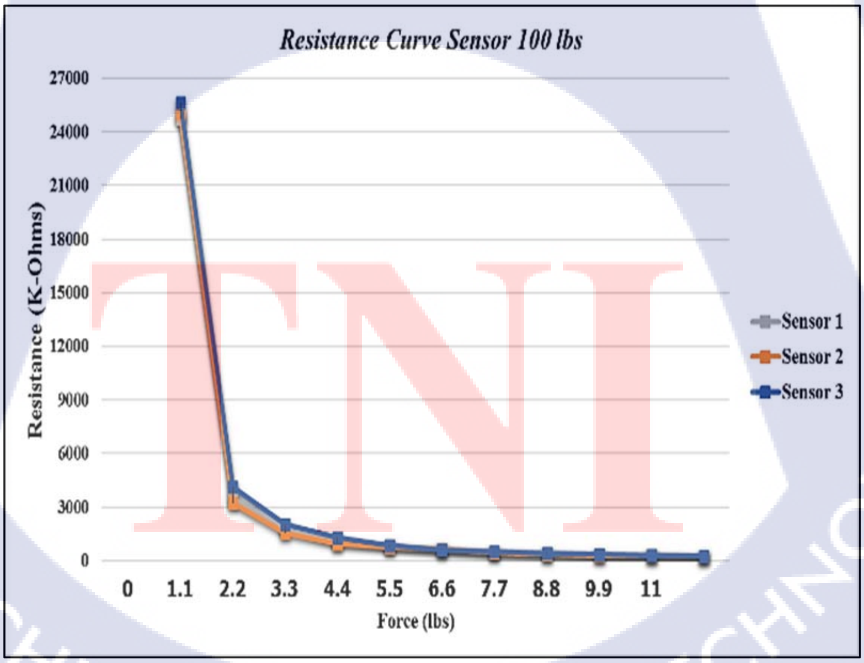


Figure 4.15 The relationship between applied force and resistance is obtained from the experimental results.

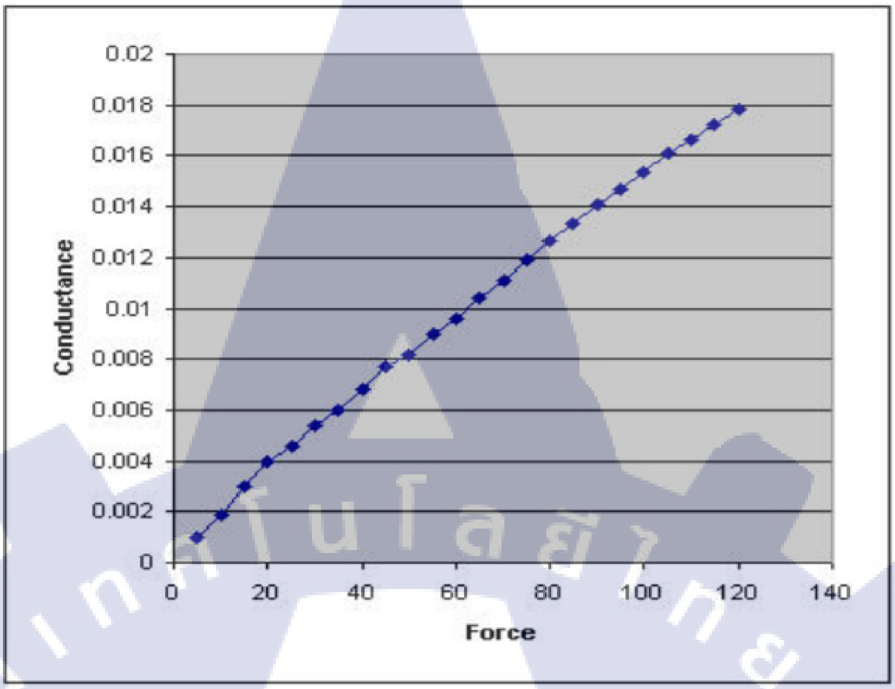


Figure 4.16 The relationship between applied force and Conductance (1/R) is obtained from FlexiForce datasheet.

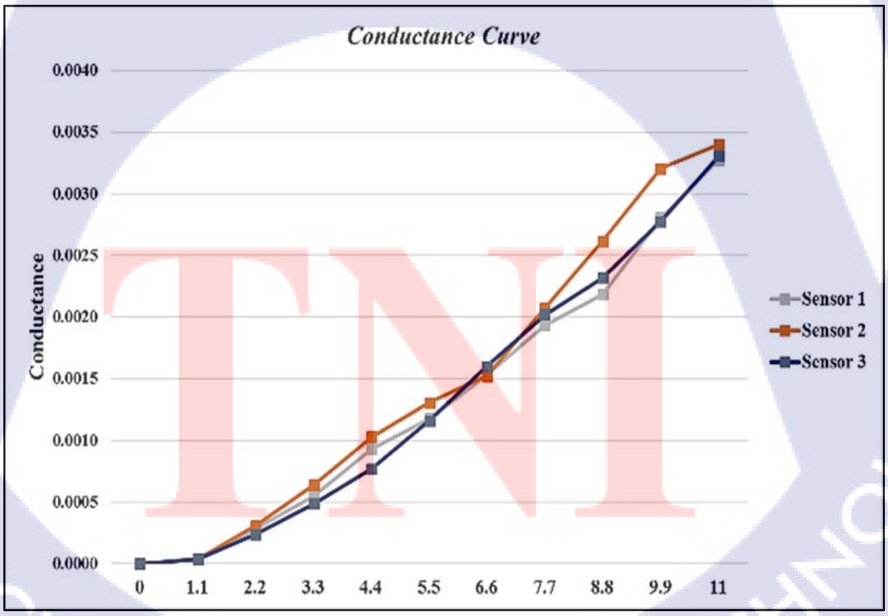


Figure 4.17 The relationship between applied force and Conductance (1/R) is obtained from experimental results.

Table 4.8 The Results of repeatability test for FlexiForce sensor A201.

Load cell	Average R_s (Ω)	SD R_s (Ω)	Repeatability
5 kgs	1.9430	0.0581	2.99 %

4.4 Conclusion

This work has alternatively attempted to design a versatile hand grip which is compatible to concise arm and hand rehabilitation robot for stroke patients. The design covers a controllable hand stick, a hand ball, and a curvature part for complete exercise. Such a hand grip is capable of providing six main functions, involving power grip, hook grip, spherical grip, pad-to-side grip, palmer grip, and Tip-to-tip grip. In addition, this research also presents the calibration of the FlexiForce sensor which is linear within the given range of loading 10-15 N with the same measurement listed in FlexiForce A201 (100 lb) datasheet. The experimental results of the force versus resistance and conductance plots show that their shape is almost close to the information from FlexiForce datasheet. Although the repeatability which is 2.99% is slightly higher than the repeatability value of the standard one which is ± 2.5%. It is because of a few numbers of repeatable times. However, this work shows the achievement of prototyping HandGlove Force measurement for measuring hand muscle's strength. In the future work, we will conduct more in term of the number of load testing, FlexiForce sensors, as well as repeatable time. Moreover, we plan to apply our hand grove prototype to post-stroke patients to tracking the progression and encouragement in the patients.

Chapter 5
Conclusion and Suggestion

5.1 Introduction

This chapter presents the conclusion of the thesis research and suggestion for further researches includes implementation.

5.2 Conclusion

This work has alternatively attempted to design a versatile hand grip which is compatible to concise arm and hand rehabilitation robot for stroke patients were successful. The design covers a controllable hand stick, a hand ball, and a curvature part for complete exercise. Such a hand grip is capable of providing six main functions, involving power grip, hook grip, spherical grip, pad-to-side grip, palmer grip, and Tip-to-tip grip. In addition, this research presents experimental design and calibration of FlexiForce sensors for hand grove force measurement utilized to post-stroke patients were also successful. FlexiForce sensor is linear within the given range of loading 10-15 N with the same measurement listed in FlexiForce A201 (100 lbs) datasheet. The experimental results of the force versus resistance and conductance plots show that their shape is almost close to the information from FlexiForce datasheet. Although the repeatability which is 2.99% is slightly higher than the repeatability value of the standard one which is ± 2.5%. It is because of a few numbers of repeatable times. However, this work shows the achievement of prototyping HandGlove Force measurement for measuring hand muscle's strength.

5.3 Suggestion

In the future work, we will conduct more in term of the number of load testing, FlexiForce sensors, as well as repeatable time. Moreover, we plan to apply our hand glove prototype to post-stroke patients to tracking the progression and encouragement in the patients. Including we will insert the elastic to hand glove prototype that it can help the patients to training or exercise hand muscles which can adjust the level of elastic resistance. Moreover, the system is used the microcontroller

ESP8266 Wi-Fi module to transmit the applied force and voltage output data, the raw voltage data from the sensors are converted to calibrated force units and displayed with real-time via Pc, Tablets screen or Smartphone by Thinkspeak application is used to store and retrieve data which is the HTTP protocol over the Internet or via a Local Area Network.

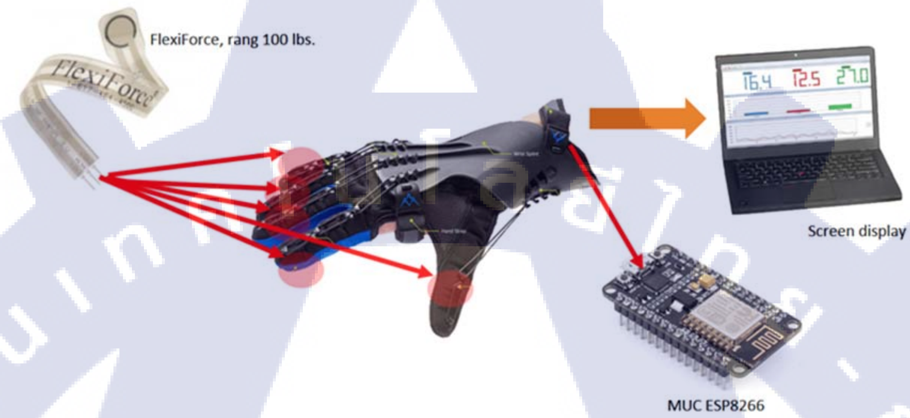


Figure 5.1 HandGlove force measurement for stroke patients.

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Appendixes

```
#include <SoftwareSerial.h>
#include "Nextion.h"
SoftwareSerial HMISerial(10, 11); //Rx ,Tx
NexNumber n0 = NexNumber(0, 1, "n0");
NexNumber n1 = NexNumber(0, 7, "n1");
NexNumber n2 = NexNumber(0, 8, "n2");
NexNumber n3 = NexNumber(0, 9, "n3");
NexNumber n4 = NexNumber(0, 10, "n4");
NexNumber n5 = NexNumber(0, 11, "n5");

NexWaveform s0 = NexWaveform(0, 2, "s0");
NexWaveform s1 = NexWaveform(0, 3, "s1");
NexWaveform s2 = NexWaveform(0, 4, "s2");

//Waveform

#define LEVEL_HIGH      (100)
#define LEVEL_LOW       (0)

int sensorPin1 = A0;
int sensorPin2 = A1;
int sensorPin3 = A2;
int sensorValue1 = 0;
int sensorValue2 = 0;
int sensorValue3 = 0;

float Caculator1 = 0;
float Caculator2 = 0;
float Caculator3 = 0;

float Sum1 = 0;
float Sum2 = 0;
```

```
float Sum3 = 0;

float Sumlb1 = 0;
float Sumlb2 = 0;
float Sumlb3 = 0;

void setup() {
  Serial.begin(9600);
  HMISerial.begin(9600);
  nexInit();
  Serial.println("setup done");

}

void loop() {
  sensorValue1 = analogRead(sensorPin1);
  sensorValue2 = analogRead(sensorPin2);
  sensorValue3 = analogRead(sensorPin3);
  Serial.print("Sensor 1 : "); Serial.println(sensorValue1);
  Serial.print("Sensor 2 : "); Serial.println(sensorValue2);
  Serial.print("Sensor 3 : "); Serial.println(sensorValue3);

  Caculator1 = sensorValue1/22.733;
  Sum1 = sensorValue1*0.284;
  Sumlb1 = Sum1*2.20462;

  Caculator2 = sensorValue2/22.733;
  Sum2 = sensorValue2*0.284;
  Sumlb2 = Sum2*2.20462;

  Caculator3 = sensorValue3/22.733;
  Sum3 = sensorValue3*0.284;
```

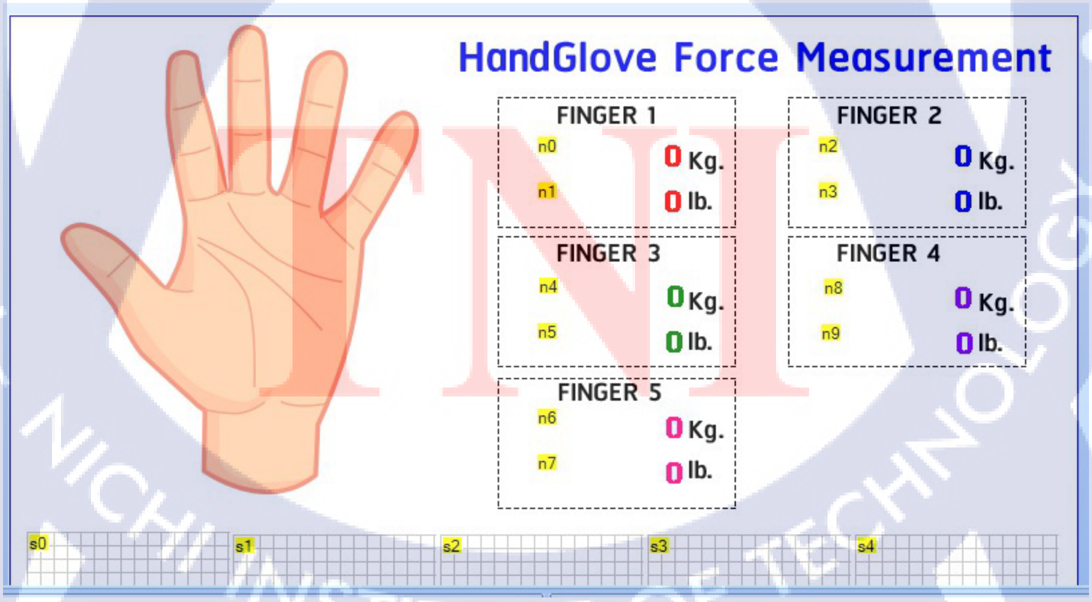
```
Sumlb3 = Sum3*2.20462;

delay(200);
n0.setValue(Sum1);
n1.setValue(Sumlb1);

n2.setValue(Sum2);
n3.setValue(Sumlb2);

n4.setValue(Sum3);
n5.setValue(Sumlb3);

s0.addValue(0,Sum1);
s1.addValue(0,Sum2);
s2.addValue(0,Sum3);
//Serial.println(A);
}
```



SRI SIVASUBRAMANIYA NADAR COLLEGE OF ENGINEERING
(Approved by AICTE, New Delhi and Affiliated to Anna University)
Rajiv Gandhi Salai (OMR), Kalavakkam – 603 110, TN, India.
Tel : +91 44 27469700, 32909138, 32909855
Fax : +91 44 27469772
www.ssn.edu.in

Administrative Office: 211/95, V.M. Street, Mylapore, Chennai - 600 004.
Telefax : +91 44 24982656, 24986474

To

Mr. Arnon Nontapha
Student ID: 59641001-9
Master of Engineering Technology Program, Faulty of Engineering,
Thai-Nichi Institute of Technology, Bangkok, Thailand.
Paper ID: ICBSII2017IN02
Office: (+66)-2-763-2600
Mobile: 085-213-8199

Dear Sir,

On behalf of IEEE sponsored International Conference on Biosignal, Image and Instrumentation (ICBSII 2017), we are pleased to inform you that your submission, entitled **"A Versatile Hand Grip Design for Concise Arm and Hand Rehabilitation Robot for Stroke Patients"** with "Paper ID ICBSII2017IN02" has been accepted for oral presentation. In this regard, we are pleased to invite you to attend our conference to be held on 16 – 18th, March 2017 at Chennai, India.

We are looking forward to see you at Chennai, India on 16 – 18th, March 2017.

Thank you,

Sincerely,

A. Kavitha (Convener – ICBSII2017)

Dr. A. KAVITHA
HEAD, DEPARTMENT OF BME
SSN COLLEGE OF ENGINEERING
OLD MAHABALIPURAM ROAD,
KALAVAKKAM, CHENNAI - 603110

3rd International Conference on Bio Signals, Images and Instrumentation (ICBSII – 2017) on 16-18th March 2017

A Versatile Hand Grip Design for Concise Arm and Hand Rehabilitation Robot for Stroke Patients

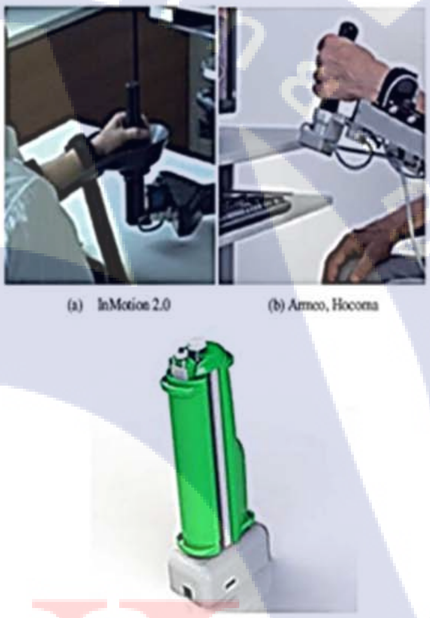
Arnon Nontapha and Wimol San-Um
Intelligent Electronics Systems Research Laboratory
Master of Engineering Technology (MET) Program
Faculty of Engineering, Thai-Nichi Institute of Technology, Bangkok, Thailand
Tel: (+66)-2-763-2600, E-mail Address: arnonnontapha@gmail.com, and wimol@tni.ac.th

***Abstract*—The number of stroke patients in Thailand has been increasing over 28,000 people annually. Most stroke patients have a problem on motion functional movement, resulting in serious disability and directly affecting to daily living ability. Rehabilitation for improving motion functional movements for post-stroke patients is therefore highly required. This paper subsequently presents a unique design of a hand grip which is compatible to concise arm and hand rehabilitation robot for post-stroke patients. Most rehabilitation robots have focused on mechanics of robot body and grip stick, but this work alternatively focuses on the design of a new stable gripper as a robot end, which provides full function for training of arm and hand muscles. The design covers a controllable hand stick, a hand ball, and a curvature part for complete exercise. The use of self-rehabilitation also embeds some sensors connecting to smart phones or tablets. Such complements motivate patients to increase repetition of movements with the record outcomes and feedback. The design of cost-effective 3-Dimentional to be implemented will also be introduced.**

Keywords*—*Rehalibitation; Robot; Sensor; Hand Grip; Post-Stroke Patients;Hand and Arm Muscles

I. INTRODUCTION

Thailand is currently facing the increase of the stroke patients over 200,000 people annually, and those people died over 28,000 people, especially elderly people [1].Most stroke patients have an effect on motion functional movement, which results in serious disability, directly affecting to activates of Daily Living (ADLs) such as eating bathing or dressing. Rehabilitation for improving motion functional movements for post-stroke patients is thereof relatively important for ADLs in practice [2]. Previous studies for solution regarding with design and development of rehabilitation devices for stroke therapy have extensively been reported. *Wansitta Kaewboon* [3] studied proposed the design for arm rehabilitation to regain functional movement focusing on triceps and infraspinatus muscles for Thai people through the use of the Electromyography (EMG) signal in order to measure and to evaluate muscle progression using Mean Square Root (RMS) and Mean Absolute Value (MAV). LabVIEW program was



(a) InMotion 2.0 (b) Armeo, Hocoma

(b) New hand-grip device for self-rehabilitation

Fig.1 Examples of hand grip stick robotic devices for motor training (a) End-effector type (InMotion 2.0 Interactive Motion Technologies, Watertown, MA, USA) [9], (b) Exoskeleton type (Armeo, Hocoma, Switzerland)[10], (c) New hand-grip device for self-rehabilitation after stroke, Imperial College London [11].

employed to control both continuous passive motion (CPM) and Direct Exercise. The results showed the device can maintain velocity and function correctly in the way that RMS and MAV of the EMG signals are increased when force level increased for both triceps and infraspinatus muscle. *Ricardo Morales et al.* [4] presented the a new concept for multimodal assistive robot that can assist the stroke patients called "Patient-Tailored Assistance", consisting of seven degree-of-freedom for safe human-robot interaction. The proposed robot had considered the patients residual physical and cognitive of physical abilities. Moreover, the patient-tailored assistance robot can be adapted to each patient's individual characteristics and it can be used for reaching task for rehabilitation purpose. Additionally, the visual feedback as well as the level of robot assistance can be adapted to the user's global state by measuring users' performance through the physiological and biomechanical monitoring systems. The result showed that the robot can increase physical and cognitive abilities of stroke patients in performing daily living activities.

Morover, *Zhibin Song et al.* [5] presented the design of the upper-limb exoskeleton rehabilitation device which was a human-machine interactive (HMI), which focuses on assistance and passive training by rehabilitation device. The experiment utilised the EMG to verify and evaluate the muscle progress at biceps and triceps muscles, and inertial sensor was used to detect position, velocity, and acceleration strength. *Akhlaquor Rahman and Adel Al-Jumaily* [6] proposed the exoskeleton rehabilitation device which is the bilateral movement training for assisting stroke patients in order to extend each digits of the impaired hand comparing to the functional movement of the healthy hand. *Eric T. Wolbrecht et al.*, [7] alternatively presented a new controller to adaptive control approach in order to learn the patient's abilities and assist in completing movements. *Rui C.V. Loureiro and William S. Harwin* [8] presented the gentle robotic rehabilitation which is a human-machine interaction (HMI), providing and helping arm reaching movement to grasp and release the objects.

Even though there have been numerous rehabilitation robot reported continuously, most rehabilitation robot have focused on mechanics of robot body, but the hand grip stick is simple and may not provide multi-function for concise hand and arm rehabilitation. Fig.1 shows some examples of hand grip stick robotic devices for motor training. It can be seen from Fig.1. that the end-effecter type, the exoskeleton type, and a new hand-grip device for self-rehabilitation after stroke are relatively simple. This work alternatively focuses on the design of a new stable gripper as a robot end, which provides full function for training of arm and hand muscles. The design covers a controllable hand stick, a hand ball, and a curvature part for complete exercise. The use of self-rehabilitation also embeds some sensors connecting to smart phones or tablets. Such complements motivate patients to increase repetition of movements with the record outcomes and feedback. In particular, this works attempts to design a cost-effective rehabilitation robot for stroke therapy well as rehabilitation devices, focusing particular features such as capability to repetitive movement, programmable resistance, objective evaluation, and sensing movement.

II. Proposed Multi-Function Hand Grip

Fig.2 show the proposed 3-dimentional versatilely multi-function hand grip design for rehabilitation robot, which can be used for six main functions. It can be seen from Fig. 2 that the hand grip comprises a hand stick, a hand ball, and a curvature part for complete exercise. For more details, it can

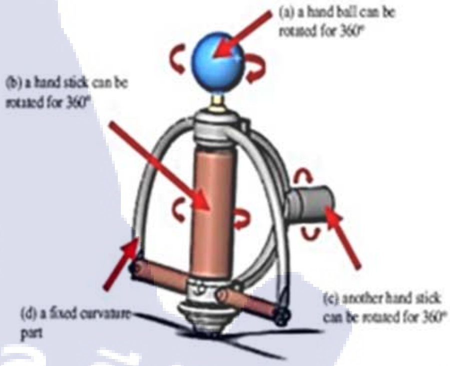


Fig.2. the proposed 3-dimentional versatilely multi-function hand grip designed for rehabilitation robot.

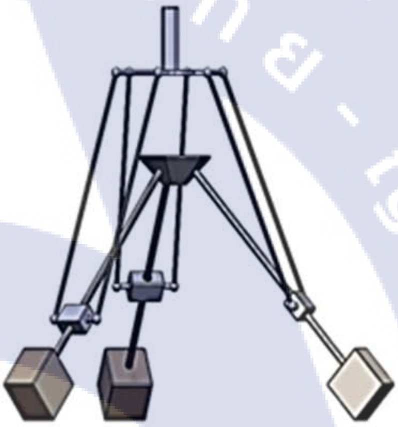


Fig.3. the 3-Dimentianal model of the designed robot at normal position where the hand grip will be attached to the top of the robot legs.

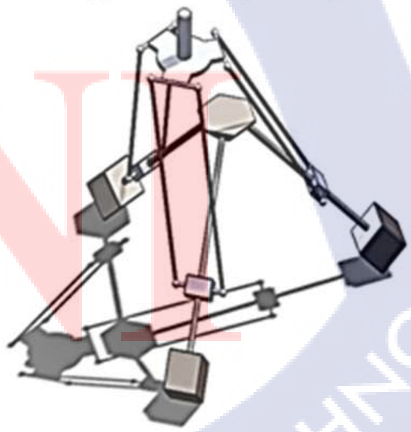
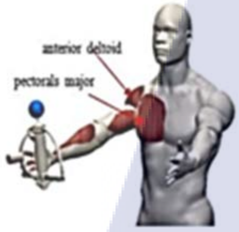
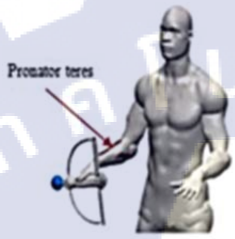


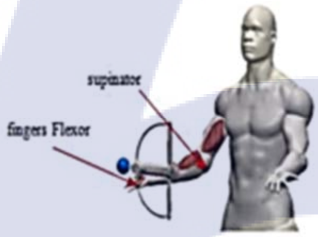
Fig.4. another 3-Dimentianal model of the robot at bending position where the hand grip will also be attached to the top of the robot legs.



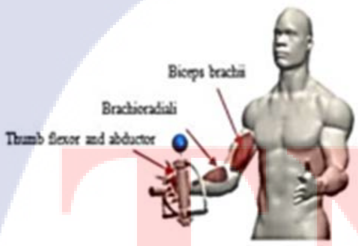
(a) Rehabilitation for Pectorals major and anterior deltoid.



(b) Rehabilitation for pronator teres.



(c) Rehabilitation for finger flexor and supinator.



(a) Rehabilitation for finger flexor and supinator.

Fig.5. Rehabilitation for hand and arm muscles using the proposed hand grip

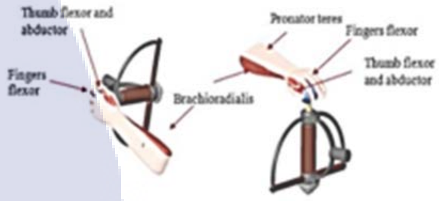


Fig.6. Rehabilitation for fingers, hand and arm muscles using the proposed hand grip at the ball part.

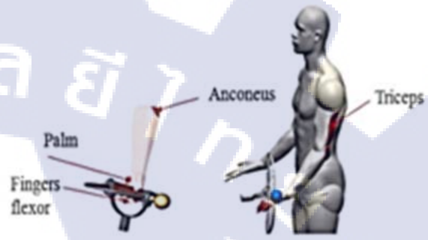


Fig.7. Rehabilitation for fingers, hand and particularly triceps muscles.

also be considered in Fig. 2 that there are four features of the designed hand grip, i.e. (a) a hand ball can be rotated for 360°, (b) a hand stick can be rotated for 360°, (c) another hand stick can be rotated for 360°, and (d) a fixed curvature part. Different parts will be used for exercising different hand and arm muscles afterwards. Fig.3 shows the 3-Dimentianal model of the designed robot at normal position where the hand grip will be attached to the top of the robot legs. The design employs three stepping motors with a slider in order to rotate the arm for 180°. For more illustration, Fig.4 depicts another 3-Dimentianal model of the robot at bending position where the hand grip will also be attached to the top of the robot legs. In the designed hand grip, some sensors are embedded for measuring body activities and connecting to Wi-Fi network for data collection, monitoring and activity analysis, involving (a) Heart Rate Sensor, (b) Gyroscope, and (c) ESP8266: Wi-Fi Module. The use of sensors will be connected to smart phones or tablets. Such complements motivate patients to increase repetition of movements with the record outcomes and feedback.

V. Physical Impacts of the Proposed Hand Grip

In this section, the 6 characteristics of hand grip model will be described in terms of physical impacts through an info-graphical illustration, involving power grip, hook grip, spherical grip, pad-to-side grip, palmer grip, and Tip-to-tip grip. Each function provides different muscle rehabilitation. Fig.5 illustrates rrehabilitation for hand and arm muscles using the proposed hand grip. It can be seen in Fig. 5 that the proposed hand grip provides rehabilitation for Pectorals major and anterior deltoid, pronator teres, finger flexor and supinator, and also finger flexor and supinator. Fig.6 depicts the rehabilitation for fingers, hand and arm muscles using the proposed hand grip at the ball part. Additionally, Fig.7 shows the rehabilitation for fingers, hand and particularly triceps muscles. Moreover, the designed hand grip can also be also used for adding some small part for particular exercising of fingers, and, and arm of stroke patients. As mentioned earlier, Figs. 8-10 illustrated the muscles are changed corresponding to tip-to-tip grip, pad-to-side grip, and palmer grip, respectively, when the hand grip model position is changed.

Fig.8. the muscles are changed corresponding to tip-to-tip grip when the hand grip model position is changed.

Fig.9. the muscles are changed corresponding to pad-to-side grip when the hand grip model position is changed.

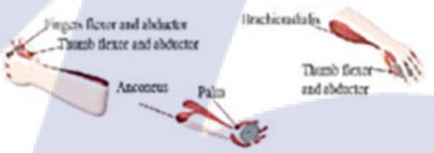


Fig.10. the muscles are changed corresponding palmer grip when the hand grip model position is changed.

VI. Discussions and Conclusions

Numerous recent studies have heralded the implementation of robotic devices into the field of stroke rehabilitation. Several reports have described the efficacy of robot-assisted therapy for improving motor and ambulatory function in patients with stroke. Most rehabilitation robots have focused on mechanics of robot body and grip stick such as End-effector type (InMotion 2.0 Interactive Motion Technologies, Watertown, MA, USA), Exoskeleton type (Armeo®, Hocoma, Switzerland), or a new hand-grip device for self-rehabilitation after stroke from Imperial College London. However, hand grip strength of the orthopedically challenged and normal persons varied as many factors depending on physical features and particular aspects of stroke patients. Even though, the hand grip may be designed differentially for different category of rehabilitation robot, this work has alternatively attempted to design a versatile hand grip which is compatible to concise arm and hand rehabilitation robot for stroke patients. The design covers a controllable hand stick, a hand ball, and a curvature part for complete exercise. Such a hand grip is capable of providing six main functions, involving power grip, hook grip, spherical grip, pad-to-side grip, palmer grip, and Tip-to-tip grip. The use of self-rehabilitation also embeds some sensors connecting to smart phones or tablets. Such complements motivate patients to increase repetition of movements with the record outcomes and feedback. The design of cost-effective 3-Dimentional to be implemented will also be introduced. The future work is to implement the actual device and test for further use in hospitals.

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