DEVELOPENT OF SWITCHING TECHNIQUE ADAPTATION ON DIFFERENT TYPES OF HAND MOVEMENT FOR EXOSKELETON HAND.

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This report is submitted in partial fulfilment of the requirements for the degree of Bachelor of Electronics Engineering Technology (Industrial Electronics) with Honours

Faculty of Electronics and Computer Technology and Engineering
Universiti Teknikal Malaysia Melaka

2025

UNIVERSITI TEKNIKAL MALAYSIA MELAKA
FAKULTI TEKNOLOGI DAN KEJURUTERAAN ELEKTRONIK DAN KOMPUTER

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek : Development of Switching Technique Adaptation on Different Types of Hand Movement for Exoskeleton Hand

Sesi Pengajian : 2024/2025

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Student Name	:	NURUL FATIHAH BINTI MOHD NORDIN
Date	:	13 JANUARY 2025

APPROVAL

I hereby declare that I have checked this project report and in my opinion, this project report is adequate in terms of scope and quality for the award of the degree of Bachelor of Electronic Engineering Technology (Telecommunication) with Honours.

Signature : ....

Supervisor Name : IR. MOHD SAFIRIN BIN KARIS

....

Date : 13 JANUARY 2025

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DEDICATION

To

My father Mohd Nordin Bin Abdul Kadir for his love, encouragement and patience.

My mother, Maslinda Binti Wahid for her love, support and sacrifice.
She continues to be a source of inspiration to me throughout my life.

My sister Nurul Syahira Binti Mohd Nordin and my brother, Khairul Afiq who are always there to offer a moment of clarity and always cheer up my day.

&

Thank you to my supervisor, Mohd Safirin Bin Karis for helping me a lot in making this project a success with sincerity, and thanks also to my comrades, Shahmi and Asmaq. And, not forgetting my other friends, Nurul Hazreen, Armyza Sharina, Farzana Syafiah, Nur Insyirah Izzati, Nur Adlina who always give me support and help.

ABSTRACT

Post-stroke patients often face significant challenges in regaining control of their limb movements, particularly their arms and hands. Electromyography (EMG) signals, commonly used to measure muscle electrical activity and strength, have proven valuable but suffer from critical limitations such as high noise sensitivity, signal distortion, and cross-talk. These challenges hinder the accuracy of muscle strength measurements, requiring complex processing techniques and leading to inconsistent output. To address these issues, this project develops a novel switching technique that integrates Force Sensitive Resistor (FSR) sensors with EMG signals, improving the reliability and accuracy of data for hand movement analysis. The system combines the strengths of both EMG and FSR technologies, leveraging FSR sensors to reduce noise interference, improve threshold values, and ensure precise data collection. Input data is derived from various hand movements, specifically focusing on the thumb, index, and middle fingers, enabling a diverse dataset for analysis. The use of Arduino IDE, MATLAB, and Excel facilitates efficient simulation, data analysis, and visualization, supporting the project's technical goals. Results demonstrate that the FSR sensor outperforms traditional EMG-only methods, delivering consistent, accurate, and noise-resistant datasets that effectively represent hand movements. This integrated approach enhances the detection of muscle activity and provides a reliable method for producing high-quality data, meeting the project's objectives. By addressing the inherent weaknesses of EMG signals, this cost-effective and efficient system contributes to advancements in post-stroke rehabilitation and exoskeleton hand technologies. The project lays a foundation for further development of switching methods, with potential applications in broader rehabilitation contexts and wearable technologies aimed at improving patient outcomes.

ABSTRAK

Pesakit selepas strok sering menghadapi cabaran yang ketara dalam mendapatkan semula kawalan pergerakan anggota badan mereka, terutamanya lengan dan tangan mereka. Isyarat Elektromiografi (EMG), yang biasa digunakan untuk mengukur aktiviti dan kekuatan elektrik otot, telah terbukti berharga tetapi mengalami had kritikal seperti kepekaan hingar yang tinggi, herotan isyarat dan cakap silang. Cabaran ini menghalang ketepatan pengukuran kekeuatan otot, memerlukan teknik pemprosesan yang kompleks dan membawa kepada output yang tidak konsisten. Untuk menangani isu ini, projek ini membangunkan teknik pensuisan baru yang menyepadukan penderia Force Sensitive Resistor (FSR) dengan isyarat EMG, meningkatkan kebolehpercayaan dan ketepatan data untuk analisis pergerakan tangan. System ini menggabungkan kekuatan kedua-dua teknologi EMG dan FSR, memanfaatkan penderia FSR untuk mengurangkan gangguan bunyi, meningkatkan nilai ambang dan memastikan pengumpulan data yang tepat. Data input diperoleh daripada pelbagai pergerakan tangan, membolehkan set data yang pelbagai untuk analisis. Penggunaan Arduino IDE, MATLAB dan Excel memudahkan analisis data dan visualisasi, menyokong matlamat teknikal projek. Keputusan menunjukkan bahawa sensor FSR mengatasi kaedah tradisional EMG sahaja, menyampaikan set data yang konsisten, tepat dan kalis hingar yang mewakili pergerakan tangan dengan berkesan. Pendekata bersepadu ini meningkatan pengesanan aktiviti otot dan menyediakan kaedah yang boleh dipercayai untuk menghasilkan data berkualiti tinggi, memenuhi objektif projek. Dengan menangani kelemahan yang wujud pada isyarat EMG, sistem yang kos efektif dan cekap ini menyumbang kepada kemajuan dalam teknologi tangan pemulihan selepas strok dan rangka luar. Projek ini meletakkan asas untuk pembangunan selanjutnya kaedah pengsuisan, dengan aplikasi yang berpontensi dalam konteks pemulihan yang lebih luas dan teknologi boleh pakai yang bertujuan untuk meningkatkan hasil pesakit.

ACKNOWLEDGEMENTS

First and foremost, I would like to express my gratitude to my supervisor, Ir. Mohd Safirin Bin Karis and for their precious guidance, words of wisdom and patient throughout this project.

I am also indebted to Universiti Teknikal Malaysia Melaka (UTeM) and my parents for the financial support through any platform which enables me to accomplish the project. Not forgetting my fellow colleague, Hazreen, Armyza, Farzana, Insyirah, Adlina, Syahmi and Asmaq for the willingness of sharing his thoughts and ideas regarding the project.

My highest appreciation goes to my parents, and family members for their love and prayer during the period of my study. An honourable mention also goes to my friends for all the motivation and understanding.

Finally, I would like to thank to fellow colleagues and classmates, the faculty members, as well as other individuals who are not listed here for being co-operative and helpful.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

Ω	-	SI unit for resistor
m	-	Mass of the object
g	-	Acceleration due to gravity (approximately 9.8 m/s^2on Earth's surface)
μ	-	Coefficient of Friction between hand
F_n	-	Normal force exerted by hand on the object
F_f	-	Frictional force between your hand and the object

LIST OF ABBREVIATIONS

*V*in	-	Input Voltage
FSR	-	Force Sensing Resistor
EMG	-	Electromyography
LED	-	Light Emitting Diode

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Post-stroke patients have trouble moving one of their limbs. Most of them will have problems moving their arms or legs. EMG Signal is one of the techniques that can measure the abilities and strength of a post-stroke patient. Electromyography or EMG studies the electrical signals from the muscles. The input is taken from predetermined muscle tissue. This technique has weaknesses such as signal-to-noise ration and the distortion of the signal. These two things are problems that may occur to get output from muscle tissue. Therefore, with the construction of the switching technique it is important to get a better input and output than using the EMG signal.

In the construction of this switching technique project, the FSR sensor is used for better data acquisition to be compared with the EMG signal. This project does not want to eliminate the acquisition of the EMG signal data, but it is used to combine it with the FSR sensor. It is very important to make the right choice to determine the best tools to use in this project based on the objectives to be achieved. Additionally, Arduino IDE, Excel Spreadsheet and even MATLAB are used to help in terms of simulation, data reading, data plotting, and data output graph. This project was produced with a prototype that would produce data that combines EMG signals and readings from the FSR Sensor to meet the set objectives.

1.2 Addressing Disadvantages of EMG Signal Through Switching Techniques using Force Sensitive Resistor

EMG signal is one of the techniques that can measure the electrical signal from the action of muscle tissue. This technique works to detect and record EMG signals. But there is a weakness for this EMG technique, which is the signal-to-noise ratio. Noise is a disturbance in the electrical signal that is not part of the EMG signal. In addition, there is also an issue of signal distortion. This distortion is caused by any frequency component in the EMG signal that cannot be changed. To deal with this issue, it is necessary to identify the appropriate components to be used to obtain signals from the muscles. Among the components suitable for measuring electrical signals from muscles are Force Sensitive Resistor . By building a switching technique project using this component can produce a better output than the signal from EMG.

1.3 Problem Statement

EMG signals emit electrical signals from muscle tissue in a similar way to nerves. EMG is prone to signal-to-noise ratio which is unwanted signal and distortion from frequency components. EMG signals have several weaknesses, such as high sensitivity to interference (noise), the difficulty of capturing deep muscle activity (cross-talk), as well as the influence of individual factors such as subcutaneous fat thickness and electrode position. In addition, the signal is non-linear and complex, requiring sophisticated processing techniques, as well as susceptible to motion artifacts, especially in dynamic activities. EMG also does not directly measure muscle strength and requires accurate equipment and adequate data interpretation by experts, so its use requires attention to careful arrangements and analysis. With a problem like this, the output signal will have a problem with the threshold value or the output graph of the electrical signal from the muscle tissue.

1.4 Project Objective

The main aim of this project is to propose a systematic and effective methodology to do a switching technique to enhance the output of the signal comes from the muscle tissue with accuracy. Specifically, the objectives are as follows:

a) To develop a switching method to represent data from different types of hand movement.

b) To analyze different types of measurement devices to represent data from different types of hand movement.

c) To analyze the performance of develop selection method based on data from different types of movement.

1.5 Scope of Project

The scope of this project are as follows:

a) Data is collected from four different types of hand movements, focusing on specific motions involving the thumb, index, and middle fingers.

b) A switching method is developed to compare EMG signals with datasets obtained from the Force Sensitive Resistor (FSR) sensor.

c) To project aims to produce more accurate output signals by addressing issues like noise and distortion present in traditional EMG signal methods.

d) The selection of components, the type of threshold, and the operational method of new technique are carefully analyzed and optimized for better performance.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Nowadays, there are many technologies that can be used to make improvements to address deficiencies or weaknesses. This kind of things needs to be emphasized to produce a more accurate reading dataset. For strategic planning and adaptive development of switching techniques on different types of hand movements using different types of datasets for Exoskeleton. It is important for utilities to develop effective methodologies to evaluate aspects of datasets, production graphs, thresholds, selection components, how components work, and the output produced correctly and efficiently by the selected component. Carefully selected searches are complete and accurate, solutions and prevention for disability reduction can be planned and implemented correctly, and in a timely and effective manner.

2.2 Understanding [Global/Current Issue] in the Literature

Through a literature review about Switching Technique Adaptation, this section will describe the selection of appropriate hand movements to acquire new datasets, explain how this switching method project operates and explain about the optimization that will be obtained from methods other than EMG signal and can make the reader understand about this project. This switching method proves that the use of Force Sensitive Resistor Sensor is one of the better methods to display the optimal output for this project. For example, Force Sensitive Resistor Sensor has direct measurement of force, simplicity and reliability, complementary information, and safety mechanism [1]. With the use of a switching method consisting of Force Sensitive Resistor, this project can produce new datasets to be optimized for graph signal production. Therefore, when planning about a new switching method from the EMG signal, it is highly emphasized in the selection of new components.

2.3 Selection of Hand Movement

The purpose for the selection of some of these hand movements is to identify what muscles will be involved to produce the output signal before the final process in this project. This project will involve three types of fingers out of five, namely the thumb, index finger and middle finger. These three types of fingers, it will be related to hand movements to identify what muscles are used when performing the types of hand movements to identify what muscles are used when performing the types of hand movements that have been set for processing before producing output on this object. There are several types of hang movements that have been set in this project, including Scissor Grip, Holding Pen, Holding Chopsticks, and Thread Manipulation. Each movements involves different muscles. The process of identifying the muscles involved is also important to ensure that this project can process the results for the next steps.

2.3.1 Scissor Grip

This movement was chosen because it involves the three types of fingers (thumb, index, and middle finger) which were chosen for placing the components used in this project. The way to do the scissor grip hand movement is by holding the scissor with the thumb and middle finger while the index finger controls the movement.

2.3.2 Holding Chopsticks

This movement was also chosen because when performing this movement, it is involving the thumb, index, and middle finger. The hand movement for this hand movement is by holding chopsticks. The way to do this type of hand movement is by holding the chopsticks between the thumb, index, and middle fingers to pick up the food.

2.3.3 Holding Pen

This movement also involves the three types of fingers that have been set for this project, namely the thumb, index finger and middle finger. The way to do the drawing or writing hand movement is by holding a pencil or pen with the thumb, index, and middle fingers while controlling movements and pressure.

2.3.4 Thread Manipulation

This last movement also involves the thumb, index finger and middle finger while doing this movement. The way to do this thread manipulation is by engaging in activities such as sewing, where the thumb, index, and middle fingers work together to manipulate the thread.

2.4 Muscle Involved

Muscles are soft tissue structures found throughout the body. The help with anything from holding body steady. Muscles move and support organs [2]. The function of the muscles based on this project is to produce electrical signals on the input components used in this project. Motor neurons give message to muscle, stimulating it. This stimulation induces electrical activity in the muscle, causing it to contract or tighten. Muscle contraction produces electrical impulses[3]. To get input through the muscles is to place the components that have been set on the surface of the hand that have the muscles involved, namely Flexor Digitorum Superficialis (FDS), Flexor Digitorum Profundus (PDS), Extensor Digitorium (ED), Flexor Pollicis Longus (FPL), Lumbricals, Interossei and Thenar Muscles. Then, the muscle signal is then sent from the surface of the sensor to the Arduino Uno which is an important component for this project and outputs the dataset reading output.

Table 2.1 The muscle involved in each set hand movement

No.	Hand Movement	Muscle Involved
1	Scissor Grip	Flexor Digitorum Superficialis
		Flexor Digitorum Profundus
		Lumbricals
2	Holding Chopsticks	Flexor Digitorum Superficialis
		Flexor Digitorum Profundus
		Lumbricals
3	Holding Pen	Flexor Digitorum Superficialis
		Flexor Digitorum Profundus
		Lumbricals
4	Thread Manipulation	Lumbricals
		Interossei
		Thenar Muscles

2.4.1 Flexor Digitorum Superficialis (FDS)

This muscle flexes the middle phalanges of the index and middle fingers, among others. The position of this muscle is the person must turn their palm upwards and rest their forearm on a flat surface. This exposes the area where the Flexor Digitorum Superficialis (FDS) is located. During the finger flexion movement, the person must bend their fingers at the middle joints while keeping the fingertips straight. This is similar with making a partial fist. To feel for the muscle, lightly press on the front of the forearm, about halfway between the elbow and the wrist. When they flex their fingers, you should feel a muscle tighten or move. This is likely the FDS. To look for the muscle movement, as the person flexes their fingers, observe the forearm. The FDS typically creates a visible bulge when it contracts.

Figure 2.1 Flexor Digitorum Superficialis (FDS) [4]

2.4.2 Flexor Digitorum Profundus (FDP)

This muscle flexes the distal phalanges of the fingers. The position for this muscle is the subject must rest their forearm on a table with the palm facing upward (supinated position). The subject need to flex the Fingers to identify FDP activity, have the subject flex their fingers into a fist while keeping the wrist relatively straight. Placement of Sensor is at on the anterior surface of the forearm, approximately two-thirds of the way from the elbow to the wrist. Place the sensor slightly toward the ulnar side of the forearm, avoiding the Flexor Carpi Ulnaris and Flexor Digitorum Superficialis, which are more superficial.

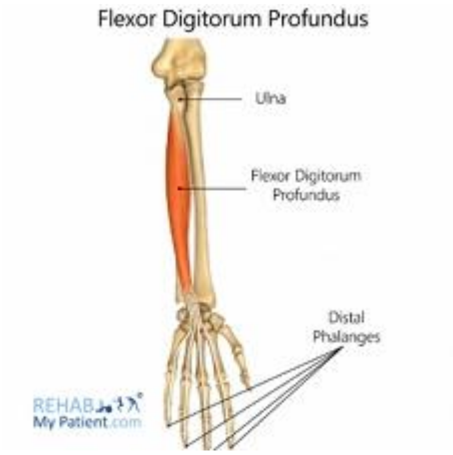

Figure 2.2 Flexor Digitorum Profundus (FDP)[5]

2.4.3 Extensor Digitorum

It extends the fingers, including the index and middle fingers. To locate this muscle, ask the subject to extend their fingers while keeping the wrist neutral. Place the electrodes on the back of the forearm, about a third of the way from the elbow to the wrist.

Figure 2.3 Extensor Digitorum (ED) [6]

2.4.4 Flexor Pollicis Longus

This muscle flexes the thumb. The flexor pollicis longus is primarily responsible for thumb flexion at the interphalangeal joints. Flexor pollicis longus is the sole muscle that flexes the thumb's interphalangeal joint, making it essential for tasks requiring hand grip. Flexor pollicis longus flexes the thumb at the metacarpophalangeal joint and helps to flex the wrist. When flex the thumb, the muscle in the lower section of forearm can be feel[7].

Figure 2.4 Flexor Pollicis Longus (FPL)[8]

2.4.5 Intrinsic

The intrinsic muscle groups are made up of tiny muscles that are only found in the numerous hand Osseo fascial compartments inside the anatomic boundaries of the wrist (proximally) and phalanges (distally). The intrinsic play a crucial role in several hand functions, including pinch and grip strength. Understanding the intrinsic hand muscle groups is critical, as denervation and loss of function can result in significant deficiencies in hand function [9].

2.4.5.1 Lumbricals

These muscles assist with flexion of the metacarpophalangeal (MCP) joints and extension of the interphalangeal (IP) joints of the fingers. The lumbrical muscles are positioned deep into the palm. These muscles arise from the FDP tendons and insert into the fingers' extensor expansions, which connect to the proximal and middle phalanges. Except for the thumb, which is only related with the first lumbrical muscle, each finger connects to two of them. The lumbricals are required for the fingers' precise grasp and fine motor control. These muscles flex the MCP joints and lengthen the PIP and DIP joints in tandem with other hand muscles [10].

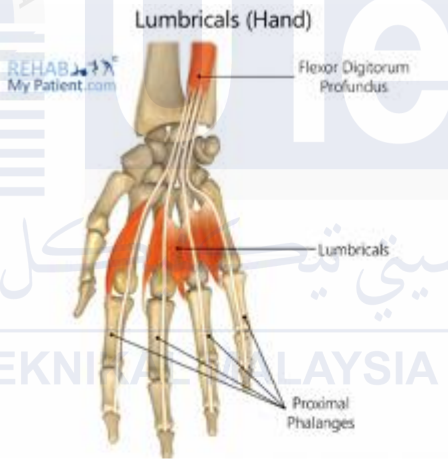

Figure 2.5 Lumbricals [11]

2.4.5.2 Interossei

The intrinsic hand muscles between the metacarpals are called the interossei. Four (or three) palmar and four dorsal muscles make up each of them. The abduction and abduction of fingers is controlled by these muscles [12]. These muscles help with abduction and adduction of the fingers.

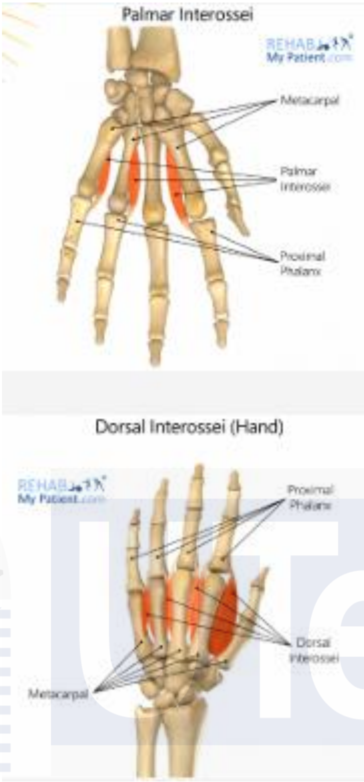

Figure 2.6 Palmar Interossei and Dorsal Interossei [13], [14]

2.4.5.3 Thenar Muscle

The base of the first digit (thumb) on the radial side of the volar hand is home to the thenar eminence. This group, consisting of the abductor pollicis brevis, flexor pollicis brevis, and opponens pollicis, controls the thumb's movements, including abduction, flexion, and opposition [15].

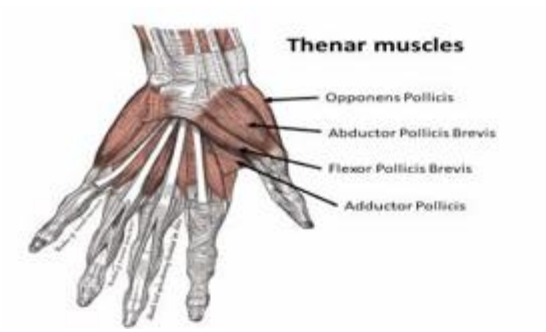

Figure 2.7 Thenar Muscles [16]

2.5 Electromyography (EMG) Signal

Electromyography, or EMG for short, is a method for measuring and recording the electrical activity produced by skeletal muscles. With this technique, electrical impulses produced by contracting muscles are detected by implanting electrodes either directly into the muscle or on the skin [17]. EMG signal is a good method to collect datasets, but given its shortcomings, it is a factor that led to the production of this project. Among the shortcomings of EMG signals in terms of output datasets are non-linearity, sensitivity to noise, signal variability, crosstalk, signal processing challenges and interpretation complexity. EMG is a useful technique to assess muscle activity and function despite this weakness. To overcome these limitations and improve the accuracy and reliability of EMG signal processing, scientists and medical professionals are still working on new techniques.

2.5.1 Non-linearity

Due to their non-linear nature, EMG signals are susceptible to several variables, including muscle exhaustion, electrode placement, and cross-talk from nearby muscles. It may be difficult to appropriately understand and evaluate the signals due to their non-linearity

2.5.2 Sensitivity of Noise

The EMG signals can be distorted, and the precision of the measurements impacted by noise and artifacts. Poor electrode contact, electrical interference, and movement artifacts are common causes of noise.

2.5.3 Signal Variability

The EMG signals exhibit considerable variability among persons, muscles, and situations, hence complicating the establishment of common guidelines or thresholds for interpretation. Inconsistencies in signal processing and interpretation may result from this variability.

2.5.4 Cross-Talk

When one muscle's electrical activity tampers with the signals captured by another, it's known as cross-talk. In cases when muscles are tightly spaced, this might lead to imprecise measurements and misunderstanding of muscle activation.

2.5.5 Signal Processing Challenges

Filtering, feature extraction, normalization, and other processes involved in processing EMG data might contribute mistakes and uncertainties into the study. Selecting the right processing methods and settings is essential to getting accurate results.

2.5.6 Interpretation Complexity

Interpreting EMG signals requires expertise and knowledge of signal processing techniques, anatomy, and biomechanics. Without proper training and understanding, the interpretation of EMG data can be challenging and prone to errors.

2.6 Components Selection

In table 2.2, the information contained in the table is about the components that have been selected to be the main components in this project. In this table there is also an explanation about the name of the component, function of measurement, mapping method, threshold, and used muscle.

Table 2.2 Component searching based on article

No	Component	Function of Measurement	Mapping Method	Threshold	Hand Movement	Used Muscle	Year
1[18]	two monochromatic stereo cameras	Measure - Hand and finger position - Orientation images Output - Position tracking - Motion data - Input for finger motion reconstruction	process of translating the raw data captured by the controller into meaningful information about finger joint angles and motion	used in motion tracking systems to define specific criteria for detecting motion, identifying key points, or segmenting data (Experimental)	Flexion Fingers	Intrinsic Muscles	2018
	three infrared LEDs (RM2)	Measure - Illumination the area where movement tracked by stereo camera - Depth sensing Output - Enhanced tracking - Depth information			Extension Fingers	Extrinsic Muscles	
2[19]	Fused Silica Plates	Measure - Force along three different axes, including shear forces and normal forces Output - Changes in capacitance	relationship between the applied force and the sensor's output signal	refer to the minimum force or pressure required to trigger a response or detection by the sensor. (experimental &mapping)	Squeezing bottle	flexor muscles	2024
	Ti Electrodes	Measure - Changes in capacitance			picking up a bottle	intrinsic hand muscles	

		Output - Changes in capacitance						
	Copper (Cu) Pads (below RM5)	- Act as output - Transmitting the detected changes in capacitance						
	IC chip (below RM60)	- Acquiring and processing the sensor’s output						
	printed circuit board (PCB) with a coil (below RM70)	Wireless data transmission in the system Output - wirelessly transmitted data containing information about the tactile sensing measurements captured by the sensor						

No	Components	Function of Measurement	Mapping Method	Threshold	Hand Movement	Used Muscle	Year
	passive components	used to enhance the functionality of the tactile sensing system Output - contributes to the overall processed data					
	Glass Pillar	used to increase the sensing sensitivity to shear force Output - related to the glass pillar's function					
	Through-Glass Vias	used for electrical connections between different layers or components within the sensor system Output - successful establishment of electrical connections critical for the sensor's operation, ensuring proper communication and functionality between the sensor elements					
3 [20]	Soft sensors	Measure - position and force applied by the fingers and thumb Output	relationship between sensor inputs and desired outputs or actions	detect specific positions or contact points based on pressure or deformation levels (Experiment)	Hand Fully Opening	residual muscles	2022

		- provide feedback on the bending and touch of the fingers,					
	Servo motors (below RM20)	actuating the fingers and thumb by providing the pulling force needed for movement. Output - rotational motion that drives the flexion and extension of the fingers and thumb, enabling the hand to perform various gestures and grasp objects with different forces and angles.			Hand Fully Closing (Power Grasp)	flexor digitorum superficialis	
	3D printed monolithic (below rm50)	mechanical framework Output - printed monolithic structure			Pinch Grip with Index Finger and Thumb	extensor digitorum communis	
	DC motors (below rm10)	providing better performance. Output - providing rotational motion to actuate the fingers and thumb of the robotic hand			Tripod Grip with Index and Middle Fingers, and Thumb		

No	Components	Function of Measurement	Mapping Method	Threshold	Hand Movement	Used Muscle	Year
	Open-source 3D printer	provide communication between the computer and the servo motors used in the robotic hand Output - control signals sent to the servo motors to actuate the desired movements in the robotic hand			Lateral (Key) Grip Index Pointing Thumb-Up/Hook		
4[21]	Safety Margin Detector (SMD)	Measure - safety margin of the grasping force optimization for both hard and soft multi-fingered hands Output - safety margin value	Parameter Identification	Safety Margin Detector (Mapping & Experimental)	Power Grip	Flexor Muscle	2021
	Grasping Force Optimization	Measure - optimal grasping force for both hand and soft multi-fingered hands based on the SMD Output - optimized grasping force that ensures a balance between grasping stability and safety margin	Quantification of Parameters		Precision Grip	Extensor Muscles	

	Finger Components	Measure - the contact force and position of the finger during doing the task Output - determining the optimal grasping.	Mapping Relationships		Pinch Grip	Intrinsic Hand Muscles	
	Force Sensors	Measure - grasping force applied by the multi-fingered hands during manipulation tasks Output - quantitative measurement of the grasping force	Establishing Thresholds		Lateral Prehension	Forearm Muscles	
			Iterative Process		Hook Grip	Shoulder and Upper Arm Muscles	
					Cylindrical Grasp	Wrist Muscles	
					Spherical Grasp		
5 [22]	Myo armbands	Measure - EMG Signal Output - Recorded EMG signals			Fist clenching	forearm muscles	2024
	Convolutional Neural Network (CNN)	Measure - analyse and classify hand movements based on the features extracted from electromyography (EMG) signals Output - one-hot vector representing the six different hand			Finger tapping		

		movements performed in the study					

No	Components	Function of Measurement	Mapping Methods	Threshold	Hand Movement	Used Muscle	Year
	Support Vector Machines (SVM)	Measure - utilized for classifying hand movements based on electromyography (EMG) signals Output - utilized for classifying hand movements based on electromyography (EMG) signals			Wrist extension		
	Random Forest (RF)	Measure - classifying hand movements based on electromyography (EMG) signals Output classifying hand movements based on electromyography (EMG) signals			Wrist flexion		
	MATLAB				Radial deviation		
	Electrodes	Measure - EMG Signals Output			Ulnar deviation		

		- classification of hand movements based on the EMG signals					
6[23]	Fiber Bragg Grating sensors	Measure - various physical parameters Output - form of changes in the Bragg wavelength of the FBGs	calibrating the Fiber Bragg Grating Hand Grip Device (FBGHGD) by applying varying known loads through a load cell	relationship between the load applied on the device and the corresponding change in wavelength of the FBG sensors (experiment)	Hand Grip	flexor digitorum profundus	2020
	mechanical package	Measure - mechanical forces such as hand grip strength in the case of skeletal muscle analysis Output - measurement of the force applied by the human hand grip			Hand Squeezing	flexor digitorum superficialis	
	The Fiber Bragg Grating sensor-based Hand Grip Device (FBGHGD device)	Measure - measure and collect real-time data analysis of human hand grip skeletal muscle force Output - force applied by the human hand grip				flexor pollicis longus	
	FBG interrogator (SM i130-700 by Micron Optics Inc.)	Measure - the changes in the Bragg wavelength of the Fiber					

		Bragg Grating (FBG) sensors Output - recorded wavelength shifts					

No	Components	Function of Measurement	Mapping Method	Threshold	Hand Movement	Used Muscle	Year
	Computer Aided Design and Drawing (CADD) software	Design and evaluation process of the Fiber Bragg Grating sensor-based Hand Grip Device (FBGHGD)					
	load cell	Measure - varying known load applied to the Fiber Bragg Grating sensor-based Hand Grip Device (FBGHGD) during calibration Output - measurement of the load applied to the FBGHGD					
7[24]	Power Window Motor (Model: WR19)	Function: - facilitate flexion-extension therapy for the arm. Output: - movement angle of the arm, which is essential for monitoring and evaluating the therapy progress of stroke patients	converting ADC voltage values from a potentiometer to specific angle values for motor movements	can be set based on sensor readings, motor movements, or other relevant data to ensure the system functions effectively and accurately. (Experiment)	Flexion Fingers	Arm muscles	2023
	RDS3235 Motors	Function: - finger movement therapy Output:	allows the system to accurately interpret the potentiometer readings and		Extension Fingers	Finger Muscles	

		- movement angle of the fingers/palm, which is crucial for assessing the effectiveness of the therapy and tracking the progress of stroke patients	translate them into meaningful angles for controlling the movement of the therapy tool during post-stroke rehabilitation sessions				
	BTS7960 43A H Motor Driver	Function: - controlling and driving the motors Output: - regulated power supply and control signals sent to the motors to ensure precise and controlled movement of the arm and fingers during therapy			Flexion Wrist		
	ESP32 Microcontroller	Function: - data transmission and communication purposes, particularly in sending therapy results to a website for real-time monitoring Output: - the data sent to the website, which includes information on the therapy progress and results achieved during the post-stroke therapy sessions			Extension Wrists		

No	Component	Function of Measurement	Mapping Method	Threshold	Hand Movement	Used Muscle	Year
	Arduino Microcontroller	Function: - controlling the motor movements, specifically the Power Window Motor and RDS3235 Motors, to facilitate arm and finger therapy for stroke patients Output: - instructions and signals sent to the motor drivers (such as the BTS7960 43A H) to regulate the movement angles of the arm and fingers during therapy sessions					
	LCD Display	Function: - show the results of the motor movements and therapy progress in real-time Output: - displayed on the LCD includes information on the angles of movement achieved by the Power Window Motor and RDS3235 Motors					

	Potentiometer	Function: - used to measure the angle of movement of the motors, specifically the Power Window Motor and RDS3235 Motors Output: - analog voltage signal that corresponds to the position of the motor shaft, which is then used to determine the angle of movement for the arm and fingers in the therapy tool					
	Jumper Cables	Function: making electrical connections between various components					
8[25]	Incremental rotary encoder sensor	Function: - measure the pedal speed and angle during hand pedalling exercises in the upper-limb FES cycling device for stroke rehabilitation. Output: - generates pulse signals with phase signals A and B, where the signals have a phase difference of 90°. These signals are processed to determine	involves mapping the error values, particularly the speed error and pulse width error, to the input of the Fuzzy Logic Controller (FLC)	error values and differences calculated during the arm cycling FES rehabilitation process. (Experiment)	hand pedalling	Deltoid muscle	2024

		the pedal speed and angular velocity of the hand strokes performed by the subject					

No	Component	Function of Measurement	Mapping Method	Threshold	Hand Movement	Used Muscle	Year
	Photoelectric sensor	Function: - used as a zero-degree reference point for the incremental rotary encoder sensor in the upper-limb FES cycling device for stroke rehabilitation. Output: - used as a reference angle for the incremental rotary encoder sensor to accurately measure the pedal speed and angle during hand pedalling exercises				Biceps brachii muscle	
	Pulse oximeter sensor	Function: - used to measure oxygen saturation levels and heart rate rhythm in the subject during hand pedalling exercises in the upper-limb FES cycling device for stroke rehabilitation				Triceps brachii muscle	

		Output: - provides information on the oxygen saturation percentage and heart rate (beats per minute) of the subject					
	Boost converter circuit	Functions: - used to increase the voltage from a 5V input to over 20V.					
	Inductors	Functions: - store energy in the form of a magnetic field when current flows through them Output: - increase the voltage level in the circuit					
	Capacitor	Functions: - employed to store and release electrical energy, smoothing out voltage fluctuations and providing a stable output voltage Output: - consistent and regulated voltage level					

No	Component	Function of Measurement	Mapping Method	Threshold	Hand Movement	Used Muscle	Year
	Diode (IN4148)	Function: - utilized for its recovery time characteristics, which are crucial for high switching frequency values in pulse-width modulation (PWM) applications Output: - ensure that the circuit can handle rapid changes in voltage levels and maintain efficiency in converting the input voltage to the desired output voltage required for the functional electrical stimulation (FES) system					
	Transistors (MPSA42 NPN and MPSA92 PNP)	Function: - utilized for their switching capabilities to control the flow of current in the circuit Output: - regulate the voltage levels and ensure the efficient conversion of the input					

		voltage to the desired output voltage required					
	Pulse generator circuit	Functions: - generate pulses with specific characteristics, such as pulse width and frequency, to control the stimulation provided to the muscles Output: - delivering the appropriate electrical stimulation to the targeted muscles during the rehabilitation exercises					
	Channel driver circuit	Functions: - regulate the activation of the channels that deliver electrical stimulation to the muscles Output: - determines when and for how long the stimulation is applied to the specific muscles, based on the input signals received from the control system					

No	Component	Function of Measurement	Mapping Method	Threshold	Hand Movement	Used Muscle	Year
	Microcontroller (STM32F103CT6)	Function: - measure various parameters and signals related to the system's operation Output: - controlling the stimulation parameters, and logic signals for the channel driver circuits to activate the muscle stimulation based on the input from the fuzzy logic controller					
	Fuzzy Logic Controller (FLC)	Function: - measure the error between the desired pedalling speed and the actual pedalling speed of the subject Output: - determines the magnitude of the pulse width output for the Functional Electrical Stimulation (FES) system applied to the muscles					

No	Component	Function of Measurement	Mapping Method	Threshold	Hand Movement	Used Muscle	Year
9[26]	Inertial Measurement Units (IMMUs)	Function: - measure accelerations and angular velocities of an object in three-dimensional space Output: - track the motion, orientation, and pose of the object in real-time	Data Collection	positional threshold (Mapping and Experiment)	Static Hand Placement	Static Hand Placement	2021
	Magnetometer	Function: - measure the strength and direction of the magnetic field in its vicinity Output: - Magnetic Field Strength - Magnetic Field Direction	Calibration		Hand Rotation	Extensor Muscles	
	Magnet	Function: - provide a reference point for determining the positions of the fingertips in relation to the hand Output: - Magnetic Field Strength - Magnetic Field Direction	Feature Extraction		3D Random Rotation	Intrinsic Hand Muscles	
	Pressure Sensor	Function: - measure the force or pressure applied to it Output:	Mapping Algorithm		Grasping Tasks	Thenar Muscles	

		- provides information about the force or pressure exerted on its sensing element - converting the pressure measurement, the sensor can also provide data on the force applied to the sensor surface					
	Sensor Fusion Algorithms	Function: - combine data from multiple sensors to improve the accuracy, reliability, and robustness of measurements or estimations Output: - provide a more accurate and comprehensive representation - improve the overall accuracy of measurements or estimations - reducing errors	Position Estimation		Writing Tasks	Hypothenar Muscles	

No	Component	Function of Measurement	Mapping Method	Threshold	Hand Movement	Muscle	Year
	3D Printed Coat	Functions: - monitoring body movements, tracking vital signs, or enhancing user interactions with technology	Validation		Flexion and Extension		
10[27]	Transcutaneous Electric Nerve Stimulation (TENS) Device	Functions: pain management and relief by delivering electrical impulses through the skin to nerve fibers			Pinch Movement		
	Electrodes	Functions: - measuring electrical signals or activity in the body Output: - electrical signals or data measurement			Pinch Movement Grasping Motions		
	Data Glove	Functions: - capture and track hand and finger movements					
	Switching Circuit	Functions: - used to control the flow of electrical current in a circuit.					
	Control System	Functions: - system of devices or set of devices that manages, commands, directs, or					

		regulates the behaviour of other devices or systems to achieve desired outputs					
11[28]	Linear Actuators	Function: - used to measure the module position of the hand exoskeleton system Output: - movement of the finger modules					
	Arduino Mega	Function: - process input signals from three different sensors	process of translating input signals	refers to the EMG threshold value (experimental)	Grasping Motions	Flexor Digitorum Superficialis	2021
	Surface Electromyography (sEMG)	Function: - measure the Flexor Digitorum Superficialis (FDS) muscle activity Output: electromyography signal generated by the muscle activity				Finger Flexion Movements	
	Flex Sensors	Function: - measure the flexion of the fingers in the hand exoskeleton system Output: - degree of flexion of the fingers					

No	Component	Function of Measurement	Mapping Method	Threshold	Hand Movement	Used Muscle	Year
	Force Sensing Resistors (FSRs)	Function: - measure the force applied during grasping and lifting movements in the hand exoskeleton system Output: - force exerted on the sensors					
	3D Printed Components	Function: - used to create the finger modules of the hand exoskeleton system					
11[29]	Six-lead Muscle Electrical Sensor	Function: - measure muscle electrical activity Output: - amplified value obtained from each EMG sensor	Data Collection	determine the start and end points of each gesture in the EMG signal data (experimental)	Fist Clenching	Biceps Muscle	2021
	Principal Component Analysis (PCA)	Function: - reduce the dimensionality of the data and extract the most important features that capture the variability in the dataset Output: - linear combinations of the original features	Feature Extraction		Finger Extension		

	Support Vector Machine (SVM) Classifier	Function: - prediction and classification of gestures in EMG-based gesture recognition systems Output: - predicted class label for each input feature vector, indicating the recognized gesture or action	Training Phase		Hand Open/Close		
	Data Segmentation	Function: - divide the collected data into meaningful segments corresponding to different gestures or actions performed by the user Output: - a set of segmented data samples, each representing a specific gesture or action performed by the user	Gesture Recognition		Thumb Movement		
	Robot Car	Function: - carrier in experiments to test the output of the EMG-based gesture recognition system	Output Control		Wrist Rotation		

No	Component	Function of Measurement	Mapping Method	Threshold	Hand Movement	Used Muscle	Year
	Root Mean Square (RMS)	Function: - quantify the magnitude of muscle activity or the intensity of muscle contractions Output: - representing the root mean square amplitude of the EMG signal					
12[30]	MyoWare EMG sensor (AT-04-001)	Function: - used to measure electromyographic (EMG) signals from muscles Output: - signal containing samples from the muscle	involves associating the Root Mean Square (RMS) values of the electromyography (EMG) signals with specific levels of muscle fatigue	classify different levels of muscle fatigue based on the Root Mean Square (RMS) values of recorded EMG samples (experimental)	Open hand	Forearm Muscle	2020
	Arduino Uno	Function: - process the analog EMG signals received from the MyoWare EMG sensor. Output: - calculated RMS (Root Mean Square) value of the EMG samples			Closed fist		
	Keypad	Function: input the Body Mass Index (BMI) class of the individual being tested			Closed fist inward		

	LCD	Function: used to display the results of the fatigue level evaluation based on the RMS value of the recorded EMG samples and the BMI class input through the keypad.					
	framework for a controlled arm	Function: used to integrate the MyoWare EMG sensor for measuring electromyographic (EMG) signals from the muscles of the arm					

Table 2.3 Characteristic of Main Component.

No.	Component	Function of Measurement	Mapping Method	Threshold	Advantages	Disadvantages
1	Surface Electromyography (sEMG)	Function: • Measure the FDS muscle activity Output: • EMG signal generated by the muscle activity	Process of translating input signals	Refer to the EMG threshold value in experimental	• Direct Measurement. • Non-invasive technique. • Real-time monitoring • Widely use in application	• Interpretation challenges. • Limited spatial resolution. • Sensitivity to movement. • Invasive needle EMG.
2	Flex Sensors	Function: • Measure the flexion of the fingers in the hand exoskeleton system Output: • Degree of flexion of the fingers			• Thin and flexible. • No problem in placing the component. • No issue with working-level voltage. • No issue with using a high potential power supply.	• Quality of components. • Not up to the mark. • Cannot connect it to a high current source.

No	Component	Function of Measurement	Mapping Method	Threshold	Advantages	Disadvantages
3	Force Sensing Resistors (FSR)	Function: • Measure the force applied during grasping and lifting movements in the hand exoskeleton system. Output: • Force exerted on the sensors	Process of translating input signals	Refer to the EMG threshold value in experimental	• Thin size. • Low cost. • Good shock resistance	• Low precision.

2.6.1 Function of measurement of each component.

The purpose of identifying the function of measurement is important in this project. It is about the signal measurement function for each component. The function according to Table 2.2 is the measure of the related muscles when performing hand movements. In terms of output, it is the result after processing the input signal from the related muscles.

2.6.1.1 Comparison between the components

Surface EMG (sEMG) measures the activity of the FDS muscle and outputs the EMG Signal that has been generated by the muscle activity [1]. But as has been explained about the lack of EMG signal this will produce an unsatisfactory output dataset due to noise or disturbance when trying to process the signal from the muscles

The function the Force Sensing Resistor (FSR) component. The function of measurement for this component is to measure the force applied during doing the hand movement and the output is from the force exerted on the sensors [1].

2.6.2 Advantages and Disadvantages of selected component

Each component selected according to this project has its own advantages and disadvantages. The choice of force sensing resistors and EMG signals depends on the specific requirements of the hand exoskeleton system, such as the need for muscle activity detection, control mechanisms, and user interaction. This sensor types have their advantages and can be beneficial depending on the desired functionality and objectives of the system. For this switching method project, it requires a better dataset output than the EMG signal. The concept of this project is, if EMG signal cannot provide a good signal dataset, switching method using FSR sensor will be used to get a more accurate dataset. The most important features in the selection of this component in terms of the advantages of accuracy reading from the component and direct measurement to avoid any noise or distortion.

2.6.2.1 Advantages of EMG Signal

The benefits of using electromyography (EMG) for muscle activity analysis include its ability to quantify muscle activity directly Referring to Table (2.2). Muscle function and activation patterns may be directly measured, which offers important new insights into muscle function. It then goes on to discuss the non-invasive method. Since EMG is a non-invasive method, it may be used in a variety of applications to evaluate muscle function and is safe and quite simple to use. Secondly, it has real-time monitoring since EMG is helpful for biofeedback and rehabilitation as it can give real-time feedback on muscle activation. In clinical and scientific contexts, it is commonly employed. Electromyography (EMG) is a widely recognized method for evaluating muscle function and identifying anomalies in research, clinical diagnosis, and rehabilitation[31] .

2.6.2.2 Disadvantages of EMG Signal

The difficulties in interpretation are one of the drawbacks of EMG. It takes skill to distinguish between noise, artifacts, and muscle activity while interpreting EMG readings since it can be a complicated process. Furthermore, EMG has a poor spatial resolution, which makes it difficult to identify activity in particular muscle parts. It gives information on total muscle activity. Furthermore, EMG is susceptible to movement artifacts and movement artifacts might alter it, which could result in inaccurate data interpretation. The invasive needle EMG comes last. The insertion of electrodes into muscles during needle EMG can occasionally cause discomfort for patients and carry a minor risk of consequences[31].

2.6.2.3 Advantages of Force Sensing Resistor

The advantages of FSR Sensor are the direct measurement of force applied by the hand. Have a simple integration and reliability in detecting pressure and force changes. Complementary information when combined with EMG signals and safety mechanism to prevent overexertion. It is ideal for applications where precise force feedback is crucial. It is useful for safety features to prevent excessive force application and can provide immediate feedback on force exertion during grasping tasks [1]. Apart from that, it has excellent shock resistance, a very cheap component, and a tiny size (less than 0.5mm)[32] .

2.6.2.4 Disadvantages of Force Sensing Resistor

The disadvantages of the FSR Sensor are in terms of non-linear response, limited durability, temperature sensitivity and the cross-talk. FSR sensors may exhibit a non-linear response to applied force, requiring calibration to ensure accurate measurements. Other than that, FSR sensors may have a limited lifespan and can degrade over time with repeated use, especially in high-force applications. In terms of sensitivity, FSR sensors may be sensitive to temperature changes, which can affect their performance and accuracy. Next, the cross talk happened when in multi-sensor setups, it is an interference between sensors, leading to inaccurate readings [1]. Because FSR sensors have poor accuracy, measurement results will deviate by at least 10% [32].

2.7 Mapping Method

A two-dimensional conceptual map of the group's ideas is created by the concept mapping approach, and it may be used to analyze ideas at the level of individual statements, clusters of statements, and groups of related clusters. In the context of the provided research on the development and control of a hand exoskeleton system, the mapping method refers to the process of establishing a relationship or correlation between different parameters or variables. Specifically, in the study, the mapping method is used to predict the relationship between input signals derived from EMG signals, wrist joint angle position, and desired wrist velocity. This mapping method helps in understanding how these parameters are related and how it influences in the context of controlling the hand movement system.

To comprehend the user's intended motions and manage the hand movement accordingly, the mapping approach based on the input from the FSR sensor entails analyzing the signals collected from these sensors. The control system can properly understand the user's hand motions and force exertion by mapping the input signals from the FSR sensor [33].

2.7.1 Mapping method of EMG signal

The Flexor Digitorum Superficialis (FDS) muscle in this investigation is the subject of particular interest for information on muscular electrical activity provided by the EMG signal. The control system can transform the user's muscular activation patterns into commands for the hand exoskeleton by evaluating the EMG data [17].

2.7.2 Mapping method of FSR Sensor

The force or pressure exerted by the user's hand is measured by the force sensing resistor (FSR) sensor. This input is essential for measuring the force applied by the user, which may be utilized to regulate the hand exoskeleton's pressure or grip strength. Processing the inputs from the FSR sensor allows us to link the user's force feedback to the appropriate movements of the exoskeleton hand [1].

2.8 Threshold

When an action or reaction is to be determined in response to input signals obtained from sensors or other sources, a threshold is a predetermined value or limit. Thresholds are utilized in the context of the hand exoskeleton system to set boundaries for certain movements or actions. For instance, raw data is gathered during the experiment's startup phase to determine threshold values for various movement kinds based on inputs from sensors like force sensing resistors (FSRs). These threshold values aid in the differentiation of various hand gestures or motions.

The hand exoskeleton's control system may also employ thresholds to decide whether to start a particular activity depending on input data from sensors such as FSRs, and surface electromyography (sEMG). The control system can precisely decipher the user's intents and initiate the appropriate motions of the exoskeleton hand by establishing thresholds for various parameters [17] .

To provide accurate control and coordination of the exoskeleton hand movements, thresholds are essential components of the hand exoskeleton system. They serve as reference points for decision-making processes that rely on sensor inputs [1].

2.9 Force of hand hold according to Friction of Coefficient (ROC)

The mass of the item, the acceleration caused by gravity (g), the coefficient of friction (μ), the normal force applied by the hand (F_n) , and the consequent frictional force (F_f) are all closely connected to the coefficient of friction between a subject's hand and an object. The item's weight, which is a crucial component in determining the normal force when the object is held or pressed on a surface, is determined by the object's mass plus the acceleration caused by gravity. To the materials in contact, the coefficient of friction is the ratio of the frictional force to the normal force. The amount of frictional force is determined by the normal force, which is frequently affected by the mass and gravity of the item. Therefore, although the coefficient of friction is essentially a material characteristic that is unaffected by mass or gravitational acceleration, in real-world situations, the frictional force experienced is precisely proportional to the normal force, which is influenced by mass and gravitational acceleration [34].

2.9.1 Defining the Coefficient of Friction between hand and the object

The frictional force resistance between two surfaces in contact is represented by the dimensionless scalar coefficient of friction. When one surface tries to move over the other, it measures the amount of frictional force that occurs between them. The materials and surface textures of the two objects in contact determine the coefficient of friction [35].

There are two types of coefficients of friction:

i. Static friction coefficient: When the surfaces are at rest in relation to one another, this is the coefficient of friction. It explains the greatest amount of friction that must be removed before the thing may begin to move.

ii. Kinetic Friction Coefficient: When surfaces slide past one another, this is the coefficient of friction. Once an item starts moving, it describes the frictional force opposing the motion.

Static friction coefficient is the crucial coefficient in this case when the item must be held stable against gravity without slipping.

2.10 Summary

EMG signal is a very popular method in the hand exoskeleton field. It has its own advantages, but from the point of view of its shortcomings, which is noise, and the slightly expensive price of the selected components is a drawback that can have an impact on the development of this project. The selection of components, hand movement and others in this project will be useful to improve this project in terms of economy or the surrounding community. The selection of all materials for this project is very rarely used by researchers before. The goal of this search is to improve this project and make the materials in this project usable for the benefit of all parties.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In general, to collect data depends on the collection and examination of measurement data. Data sets according to scientific research initiatives are temporary results. The dataset will not be published in a short period of time, but if the output is published in a short time, the dataset is not accurate, cannot be read clearly, or cannot be processed correctly When collecting data. But, among the factors related to dataset collection are models or components and parameters. With the factors related to the components and the parameters can influence in terms of collecting a better dataset [36].

3.2 Selecting and Evaluating Tools for a Sustainable Development

The technology and components that will be used for dataset collection, analyzing the dataset must be carefully selected and studied for the development of switching technique adaptation on different types of hand movement using different types of datasets of exoskeleton hand. This section requires several methodological factors, including determining the capabilities of each sensing component, microcontroller, analyzing the interoperability of various instruments and software, and considering the impact of the project's environment. The social and economic impact of this project also needs to be considered. For example, all the datasets that have been obtained while doing this project can be understood by various parties involved and interested, and the lack of various tools should also be considered. Various methods and techniques that can be used to support this part of the methodology include testing of each sensing component, the use of appropriate open-source software to promote accessibility and transparency and conducting a life cycle assessment to assess the impact of the environment and the human environment in this project. Researchers and testers can also ensure that this switching method project initiative can be successful, durable, able to choose, and meaningful by carefully selecting and evaluating the instruments used for this project.

3.3 Methodology

This thesis describes a new switching method for exoskeleton hand movement. The important content in this is the search, filtering and selection process that is new or has not been made by anyone yet. This search is made based on the selection of components, software, and hand movement. It aims to create a better dataset of EMG signals. The design method of this project is to conduct experiments that use more extensive hand movements, better sensing components and suitable software to implement this project. Figure 3.1 shows the process of finding the tools used for this project.

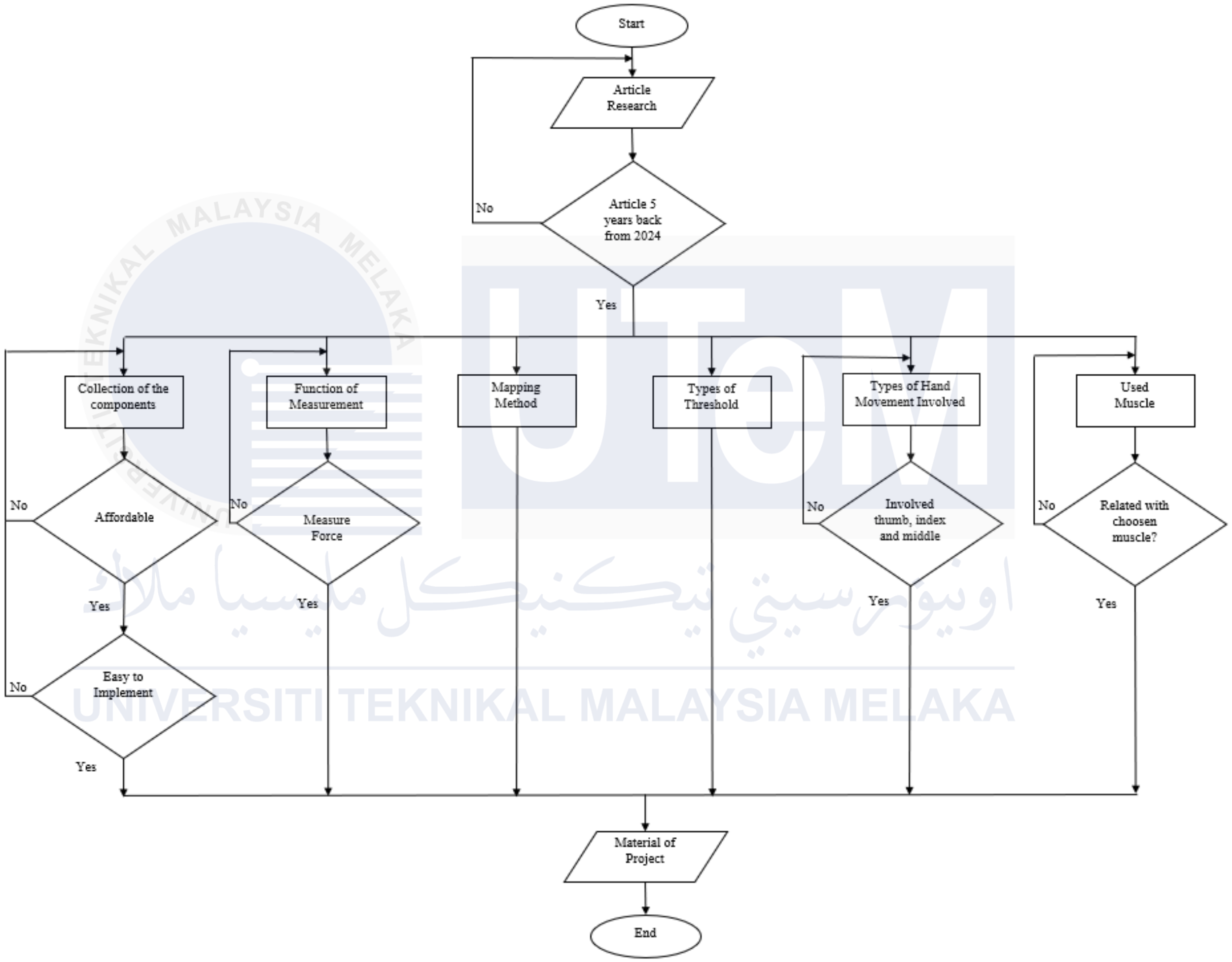

Figure 3.1 Article research in finding tools, measurement, mapping method, threshold, hand movement and used muscle

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3.3.1 Process of article search

Referring to Figure 3.1, in the process of searching for tools, measurement, mapping method, threshold, hand movement and muscles used are based on article research that was done to be made into a draft before implementing this project. This process is very important to do because it affects in terms of financial factors, quality, durability, accuracy, ease of use, identifying the advantages and disadvantages of components, and matters related to the draft and the literature review.

For the article research process, this project needs to use articles published in the last 5 years from the year 2024. The next step is the process of selecting the components to be used. It should have features such as affordable, less noise, and easy to implement in this project. In addition, the process of finding a function from the measurement is also important because this project focuses on measuring the force exerted from the sensor. Followed by mapping method and types of thresholds. After that, the process of searching for types of hand movement involved should use 3 types of fingers that have been set and are rarely used, namely the thumb, index finger and middle finger. And the muscle used in each selected hand movement must be related to the muscles involved between the three fingers that have been set.

After completing the process for finding tools, measurement, mapping method, threshold, hand movement and used muscle, the material of this project can be collected.

3.3.2 Process to detect muscle

The process to detect muscle for each muscle is to use the other hand or use someone else's hand. The first aspect is to understand the muscle anatomy. Before identifying the type of muscle, it is necessary to understand the basic theory of the muscles involved. Next, with a visual inspection. Look at the area that has been researched. Muscles will often become visible when they are bent or under tension and look for the overall shape and size of the muscle.

Another way that can be used to identify muscles is by using the palpation technique. The trick is to use your fingertips to gently press and feel the area because the muscles will be more tense than the surrounding tissue such as fat. In addition, using the muscle contraction method, which is by asking the subject to flex the muscles that want to be detected.

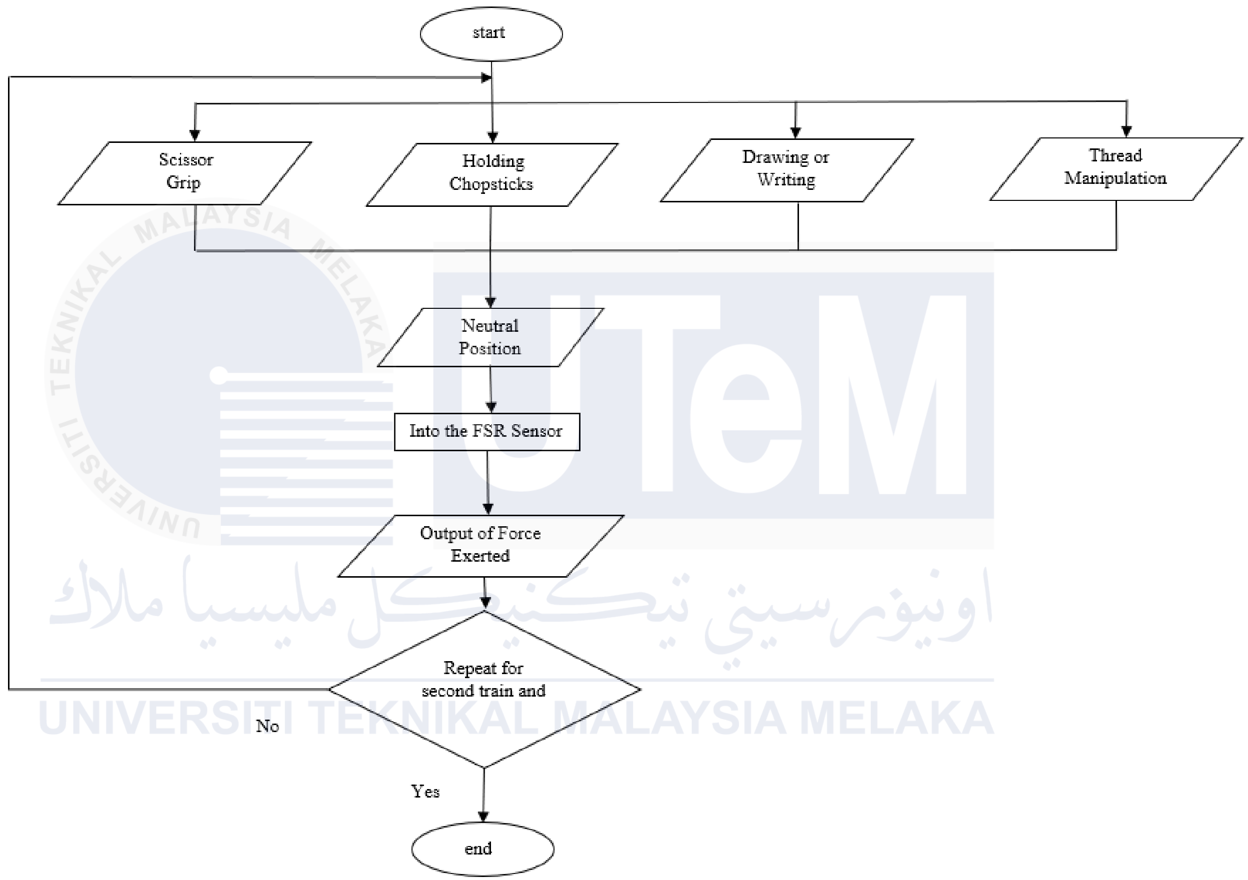

Figure 3.2 Data collection using FSR sensor with different hand movement and different position

3.3.3 Switching method using FSR with different hand movement and position

Referring to Figure 3.2, in the beginning of this process, it analyzes all four hand movements that have been determined according to the previous chapter, namely scissor grip, holding chopstick, holding pen, and thread manipulation. For each hand movement, one positions should be made, namely neutral for the movement. The FSR sensor that is constructed and placed on the finger will produce an output for the force exerted from the sensor. Next, this process needs to be repeated to get the dataset for the second train and the test.

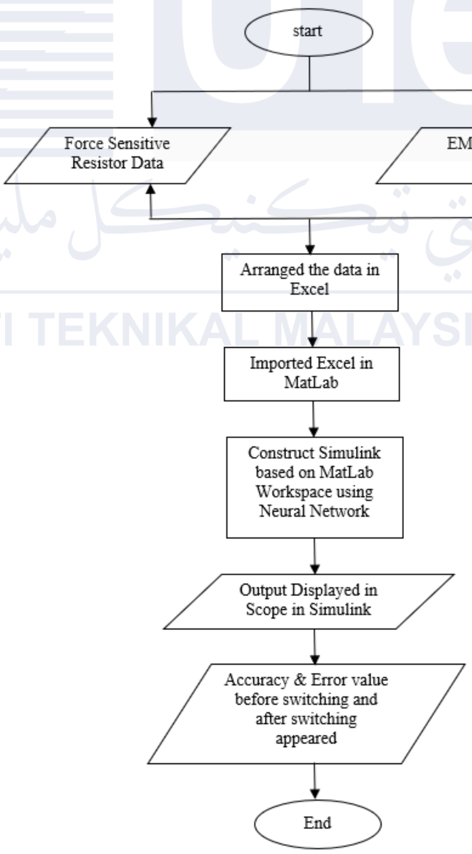

Figure 3.3 Switching method between EMG signal and FSR sensor

3.3.4 Switching method between EMG signal and FSR sensor

Referring to figure 3.3, The flowchart depicts the process of combining Force Sensitive Resistor (FSR) data with Electromyography (EMG) signals for analysis and simulation. Data from FSR and EMG sensors are first gathered and sorted in Excel before being transferred into MATLAB for further analysis. A Simulink model is then created from the MATLAB workspace data, which includes a Neural Network for analysis or pattern recognition. A scope block visualizes the Simulink model's output, allowing for real-time monitoring of system activity. Finally, accuracy and error numbers are generated and shown for comparison before and after a switching event to complete the procedure. This method is most likely used in domains like biomechanics, robotics, and medical device development.

3.3.5 Experimental setup

This part is the most important part for this project. This thesis presents a new and more accurate switching method to collect a new dataset for each hand movement that has been set for this project. The collection of datasets used in this project is focused on data collection, better graph production. The chosen approach is based on qualitative, experimental, and quantitative types, which aims to build this switching method project to produce a better dataset for observation that is easier for outsiders to understand. This design method is experimental, which uses predetermined components to build this project for improvement.

3.3.5.1 Block Diagram

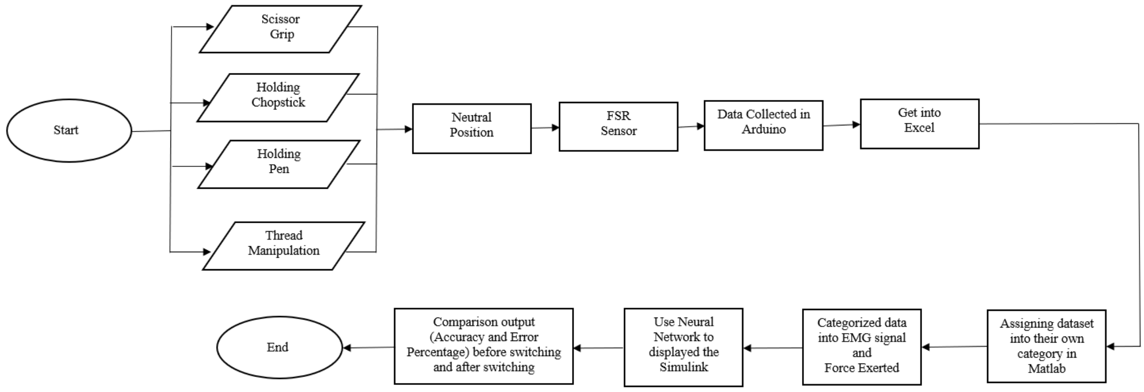

Figure 3.4 Block diagram of the switching method system

A system, project, or situation is graphically represented using a block diagram. It offers a functional perspective of a system and shows the connections between its many components. Block diagrams are very useful for engineers to represent system components and comprehend how they are interrelated.

Referring to Figure 3.4, it is a switching method system. This block diagram outlines a process for task execution, data acquisition, categorization, and analysis using sensors, Arduino, MATLAB, and neural networks. It begins with four tasks: scissor grip, holding chopstick, holding pen, and thread manipulation, followed by transitioning to a neutral position for standardization. Data is collected using a Force Sensitive Resistor (FSR) sensor, processed via Arduino, and exported to Excel. In MATLAB, the dataset is categorized with EMG signals (measuring muscle activity) and force exerted during tasks. A neural network is then employed to analyze the data and display results in Simulink. Finally, the process compares outputs, including accuracy and error percentages, before and after switching, to evaluate performance, concluding the workflow.

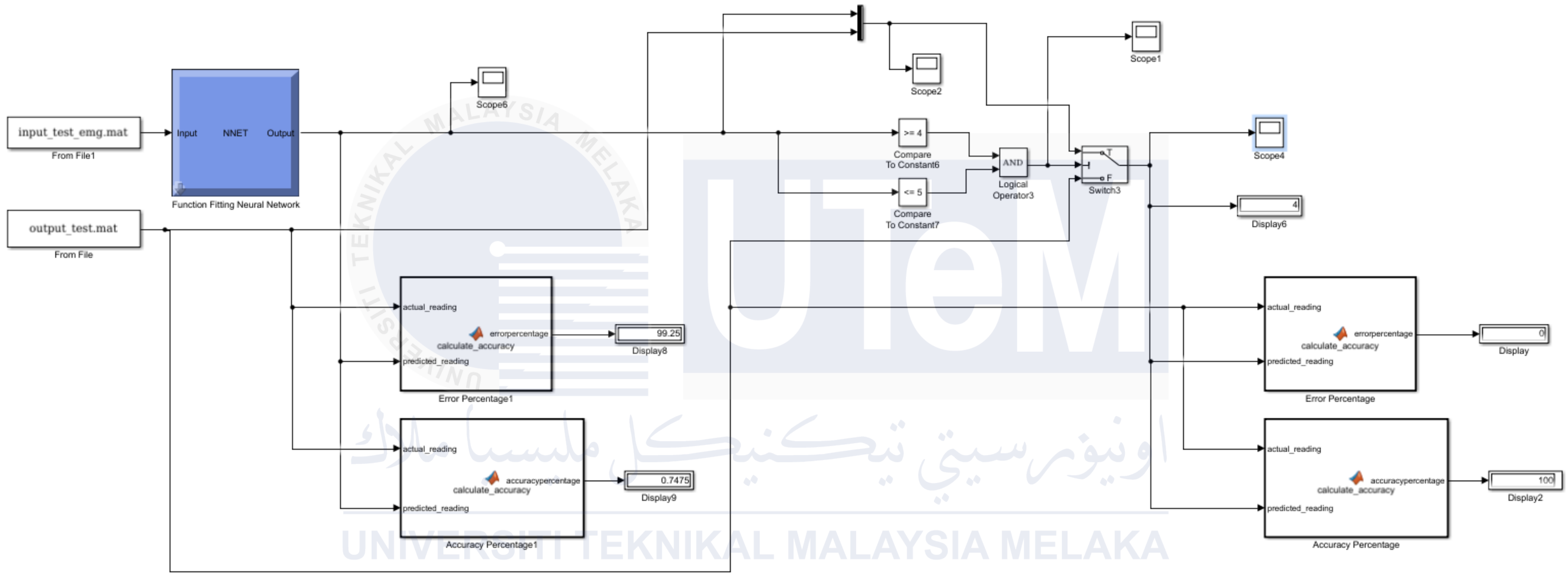

Figure 3.5 Simulation circuit for switching method in Simulink

Referring to Figure 3.5, it is a switching method system. Based on the figure above, it is a block diagram for simulation in Simulink. There are several components used to produce the switched output. Simulink block diagram represents a system that processes neural network outputs and evaluates their performance using accuracy and error metrics. For the input, this system takes two primary inputs which is "input_test_eng.mat" (input data to the neural network) and "output_test_mat" (actual target/output data from FSR). Next, compare to constant block is used to set the range for combined dataset and so on. After that, the ANN data selected from the range is used as data that can be taken to be connected to the actual data from the FSR sensor. Each scope is placed on each switch to produce the switched output graph for each object. And the four switched input output data are combined using the "MUX" block from Simulink to be combined to produce the full switching graph.

3.3.5.2 FSR Sensor circuit software simulation

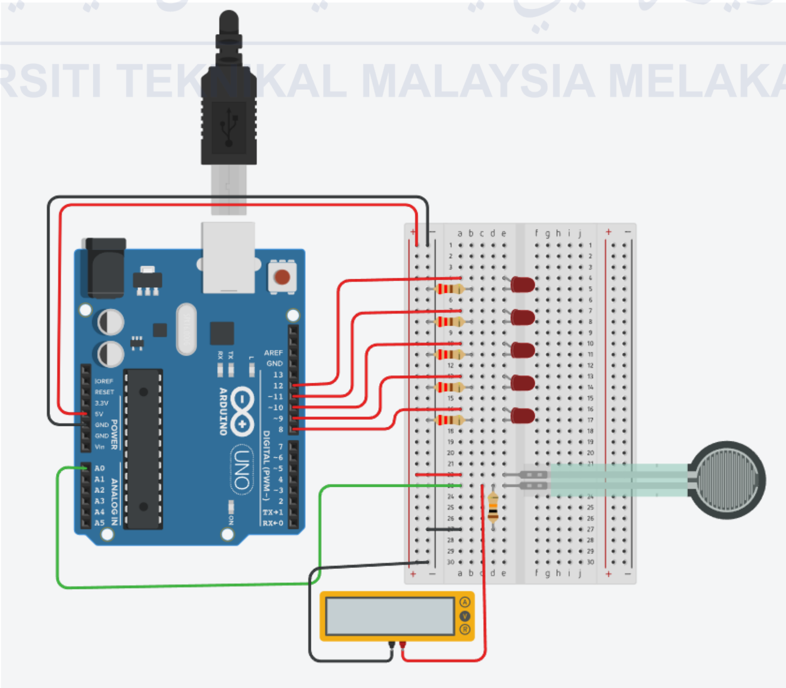

Figure 3.6 FSR Sensor Circuit software simulation using Tinkercad

Referring to Figure 3.6, it is a sample of one FSR sensor connected to the A0 port at Arduino Uno. It is still the same concept that have been used which is the voltage divider because Arduino Uno cannot read value of resistance. Next, add Vin to the 5V port to supply power to the circuit. Next, the placement of the red led are not used in the hardware circuit, but for this part, it wants to explain about the threshold value, and each of the LED is coded with certain value of threshold.

3.3.5.3 Hardware Circuit of FSR Sensor

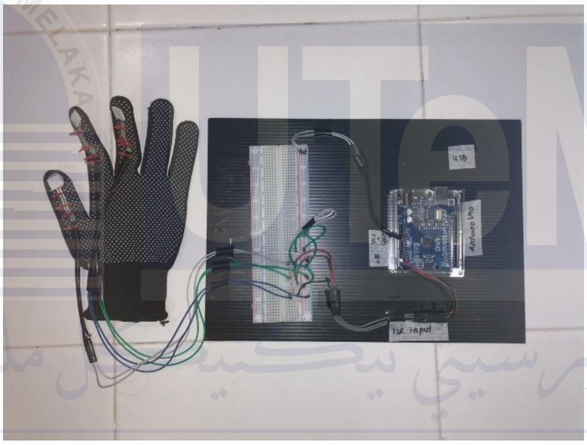

Figure 3.7 Hardware Circuit of FSR Sensor

Referring to Figure 3.7, the construction is including the FSR Sensor, 220Ω resistor, Arduino Uno, and some of jumper cables. The left sight of the FSR sensor is connected to ground. The right sight of the FSR Sensor is connected to resistor, Vin = 5V and from resistor go to the input A3, A4 and A5.

3.4 Hardware Components

The hardware components used in this project are from a good selection of components. Hardware components for processing are FSR Sensor and Arduino Uno. Next, use a breadboard and a resistor to construct the circuit of this project and use cloth material gloves.

3.4.1 FSR Sensor

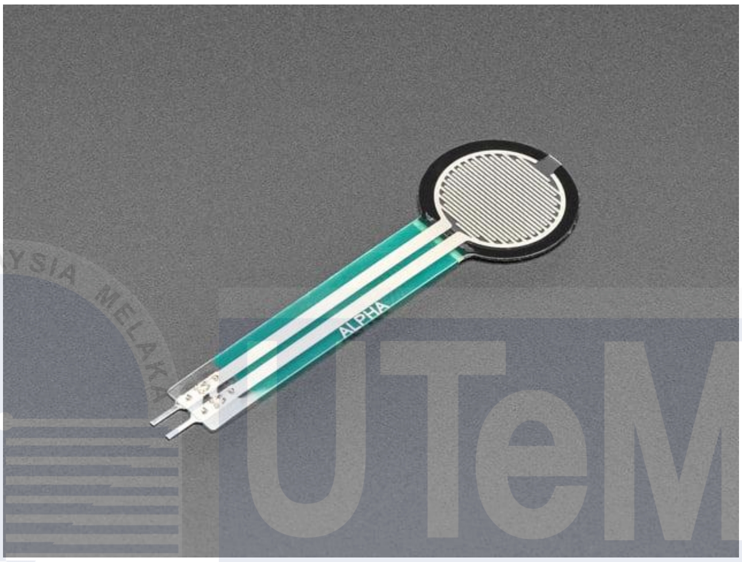

Figure 3.8 FSR Sensor

FSRs are sensors that identify weight, squeezing, and physical pressure. They are inexpensive and easy to use [37]. As pressure is increased, the FSR's resistance varies. The sensor appears as an infinite resistor (open circuit) in the absence of pressure, then decreases in resistance with increasing pressure [37].

3.4.1.1 Pin Configuration for FSR Sensor

The FSR sensor has two terminals. Unlike diodes, the FSR sensor does not have polarized terminals. Thus, there are no good or terrible things. This sensor needs a voltage between 3.3- and 5-volts DC to operate, and any kind of interface can provide this value. Pin P1: This pin is generally connected to GND pin of the power source. Pin P2: This pin is generally connected to the positive terminal of the power source.

3.4.2 Arduino UNO R3

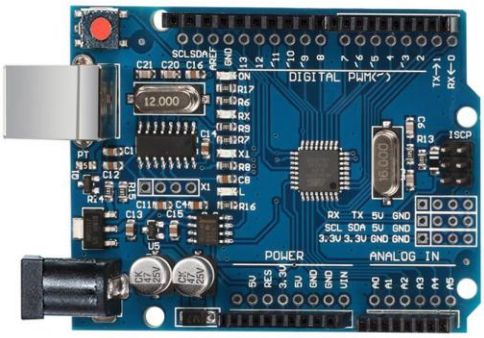

Figure 3.9 Arduino UNO R3

An ATmega328P-based microcontroller board is the Arduino UNO [38]. The Arduino UNO is an open-source, programmable microcontroller board that is inexpensive, versatile, and simple to use. It may be used in a wide range of electrical projects. This board can operate relays, LEDs, servos, and motors as an output and can interact with other Arduino boards, Arduino shields, and Raspberry Pi boards [39].

3.4.2.1 Pin Configuration for Arduino Uno

The AVR microprocessor Atmega328, six analogue input pins, and fourteen digital I/O pin six of which are utilized for PWM output—are all features of the Arduino UNO.

Description of each pin:

i) ATmega328: This is the board's brain, where the program is kept.

ii) Ground Pin: The board has many ground pins integrated into it.

iii) Pulse Width Modulation (PWM): There are six PWM pins on the PCB. Pulse Width Modulation, or PWM for short, allows us to regulate the LED's brightness as well as the DC and servo motors' speeds.

iv) Digital I/O pins: The board has 14 digital (0–13) I/O pins that may be used to connect other electrical parts.

v) Analogue Pins: The board has six inbuilt analog pins. These pins could read analog sensors and translate them into digital signals.

vi) AREF: To set an external reference voltage, utilize the analog reference pin.

vii) Reset Button: To reset the code stored into the board, press this button. Pressing this button will reset the board to its initial state, which is helpful in case the board hangs up.

viii) USB Interface: Using this interface, you may upload Arduino sketches and connect the board to a computer (an Arduino program is called a sketch).

ix) DC Power Jack: This is how a power supply powers up the board.

x) Power LED: When the board is linked to a power source, this power LED turns on.

xi) 3.3V: Your projects will receive 3.3V electricity from this pin.

xii) 5V: Your projects will receive 5V electricity from this pin.

xiii) VIN: It is the voltage that is supplied to the UNO board as input.

xiv) Voltage Regulator: The voltage that enters the board is managed by the voltage regulator.

xv) SPI: SPI, or Serial Peripheral Interface, is an acronym. This connection uses pins 10 (SS), 11 (MOSI), 12 (MISO), and 13 (SCK).

xvi) Tx/ Rx: Serial communication uses pins TX and RX. While RX is a receive pin used to receive serial data, TX is a transmit pin used to send serial data.

The pin used for this project is in the Power section which is the Ground Pin and the 5.5V pin. Next, use analog input pins from A0 to A5 to insert component pins into separate ports.

3.4.3 Resistor (220Ω)

Figure 3.10 Resistor 220Ω

A passive electrical part with two terminals that are used in electrical circuits to control or limit the flow of electric current. Reducing current flow and lowering voltage in a specific area of the circuit is the primary function of resistors. It is constructed from copper wires wound around a ceramic rod, and an insulating paint is applied to the resistor's outside [40].

3.4.4 Breadboard

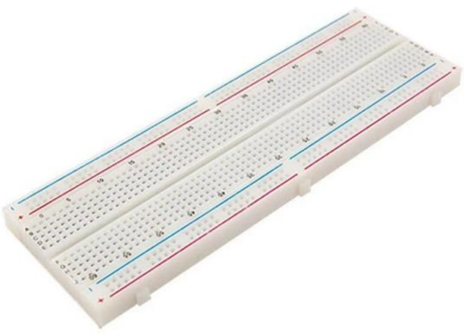

Figure 3.11 Breadboard

The basis for building and prototyping electronics is simply a breadboard, often known as a protoboard. Using a breadboard makes it simple and quick to build makeshift electrical circuits or conduct circuit design experiments. Because the perforated plastic casing beneath the rows and columns of internally linked spring clips makes connecting components or wires easy, breadboards are a great tool for developers. The X and Y dimensions of the grid's precisely matched spring clip holes are separated by 0.1. [41].

3.4.5 Jumper Wires

Figure 3.12 Jumper Wires

Simply said, jumper wires are cables having connector pins on either end that may be used to join two places together without the need for solder. Typically, jumpers are used in conjunction with breadboards and other prototype equipment to facilitate the simple modification of circuits as needed. Quite easy. Indeed, jumper wires are about as fundamental as it gets [41].

3.5 Software

Software is the most important element in the development of this project because it functions to collect, analyze, filter data and so on to publish datasets and outputs. It is used during the middle of the process, which is after collecting data from the input to be processed.

3.5.1 Tinkercad

Figure 3.13 Tinkercad

An online tool for making, customizing, and sharing 3D models is called Tinkercad. Its accessible and user-friendly interface make it especially well-liked by novices, teachers, and enthusiasts. Tinkercad is an adaptable tool that facilitates a variety of artistic and educational endeavors pertaining to electronics, coding, and 3D modeling.

3.5.2 MATLAB

Figure 3.14 MATLAB

MATLAB or MATrix Laboratory an interactive environment and high-level programming language created by MathWorks. It is extensively utilized in programming, visualization, and numerical computing. Because of its strong capabilities for managing and analyzing massive volumes of data, MATLAB is especially well-liked in the fields of engineering, science, and applied mathematics. It performed numerical computation, data analysis and visualization, algorithm development, simulation and modelling, toolboxes and add-ons, interfacing with other languages and systems and application development. The common applications of MATLAB are in engineering and scientific research, financial modelling, image and signal processing, control systems and education.

3.5.3 Arduino IDE

Figure 3.15 Arduino IDE

The open-source electronics platform Arduino is built on user-friendly hardware and software. It is composed of a development environment for building software to operate on the microcontroller and a microcontroller, which is a basic computer on an integrated circuit (IC). The main features and function of Arduino are the microcontroller board, open-source, development environment and wide range of board and shields. The functions and the usage of this software are in prototyping, education, DIY projects, research and development and automation.

3.5.4 Excel

Figure 3.16 Excel

Microsoft created Excel, a spreadsheet tool that is a component of the Office software package. It is frequently used for organizing, analyzing, and visualizing data. Spreadsheets may be created and edited in Excel to store data, carry out computations, and produce graphs and charts.

3.6 Summary

This chapter presents the proposed methodology for developing this project with improvements and renewals from existing projects. This project wants to achieve the stated objectives successfully and meet the desired criteria in this field. The focus of this methodology is to develop projects that are affordable, easy to use, user friendly, last long durability, and low cost so that other people can use it without any problem. This method also aims to build a new dataset from the sensors that have been selected for this project with characteristics related to the literature review so that the production will be more optimal than the existing project. The ultimate intent of the method is not to obtain the highest accuracy, but, for efficiency, easy to use and manipulate and practicality of deployment on a large-scale distribution network.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents results and analysis on the development of a new switching method that can produce better datasets by using FSR Sensor. Then, this switching method can be used to replace the EMG signal for dataset production. A case study is done to show the usability of this new switching method. This case study that has been done is referred from researchers who have previously been either in Malaysia or outside Malaysia. It is important to note that, this case study aims to illustrate the proposed methodology, without doubt to carry out this project. This switching method uses subjects to do this experiment at a set time. These results are confirmed based on the results that have been studied while understanding the theoretical process of how each tool used is studied.

4.2 Results and Analysis

This section shows all dataset results for each hand movement using FSR sensor. The attached output includes all the features that have been discussed in the literature review section, which is a clearer output compared to the EMG signal. It can prove that the FSR sensor are good components for measuring data from any surface.

4.2.1 FSR Sensor Output

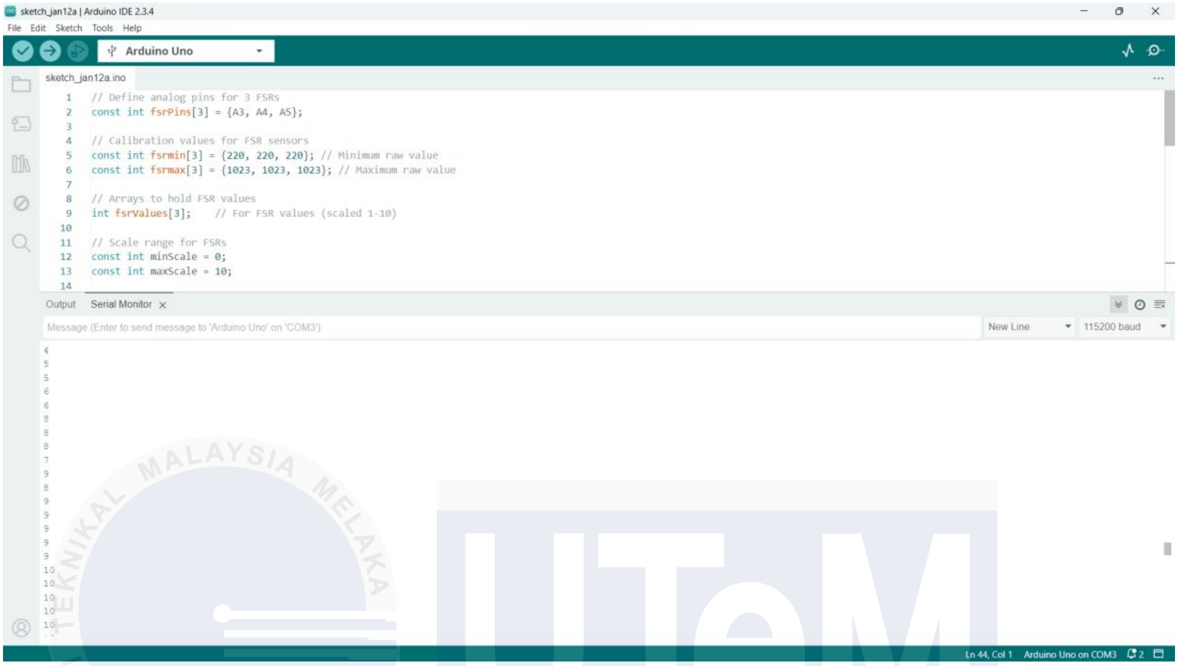

Figure 4.1 Addition of each value from FSR Sensor at Serial Monitor

Referring to Figure 4.1, it shows the dataset of FSR sensor value shows the total number for all three FSR sensors used. The program runs for 10 seconds, whichever comes first. After that, it stops and enters an infinite loop. In this data collection experiment, the user needs to perform this task by holding the object stably and holding it with the force that has been set for one object, namely holding scissors (12-13), holding chopsticks (9-10), pens (7-8) and thread manipulation (4-5). All these readings go to the excel.

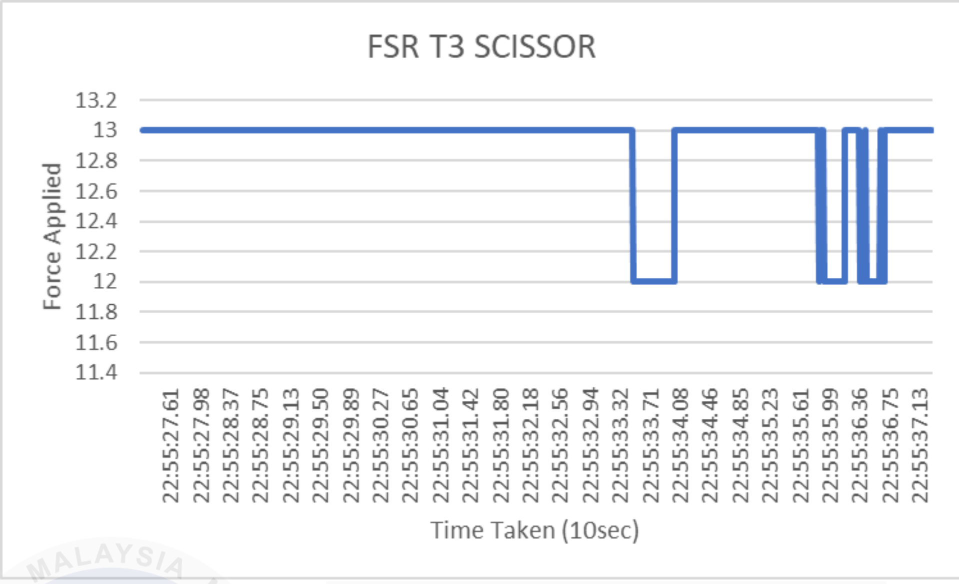

Figure 4.2 FSR Output on Excel

Referring to Figure 4.2, every data output from Arduino IDE Serial Monitor, namely the FSR sensor, every data is automatically recorded in Excel using "Data Streamer". Data streamer outputs on Spreadsheet and graph that has been set also on "Data Streamer". Graph on "Data Streamer" shows to the user that user needs to hold the object in the range that has been set on each object. As an example, in Figure 4.2, the number range for holding scissor is around 12 to 13.

4.2.2 Simulink Output

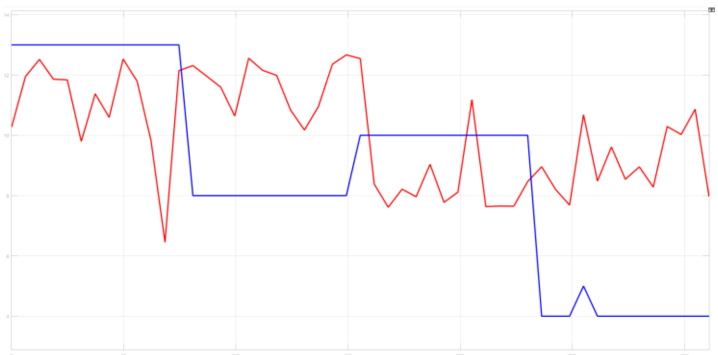

Figure 4.3 Combination output from EMG signal and FSR sensor data

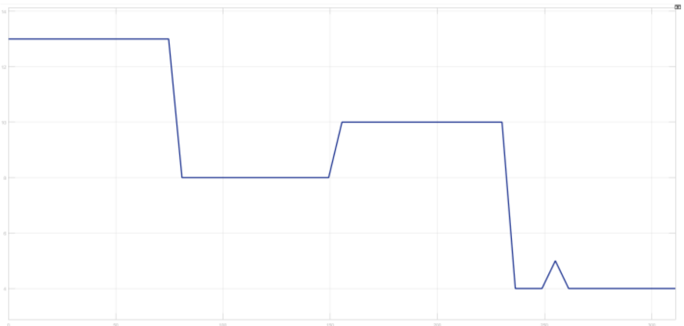

Figure 4.4 Switching output between EMG signal and FSR sensor data

Referring to Figure 4.3, the output is the 311 data from the combination of data from to EMG signal (Red) and data from the FSR sensor.

Switching technique is performed and the output is produced as in Figure 4.4. The output contains the EMG signal selected within the range specified in the "Compare-to-Constant' block in Simulink and combined with the FSR data using the "AND Logic" block to combine the data selected from the range in the EMG signal.

4.2.3 Simulation Formula in MATLAB Function Block

$$Error\ \% = \frac{|predicted\ reading - actual\ predicted|}{actual\ predicted} \times 100 \quad (4.1)$$

$$Accuracy\ \% = 100 - \frac{|predicted\ reading - actual\ predicted|}{actual\ predicted} \times 100 \quad (4.2)$$

Referring to (4.1) and (4.2), these formulas are used to put in the "MATLAB Function" block in Simulink to calculate the performance of before switching and after switching.

4.2.4 Accuracy and Error Percentage in Simulation

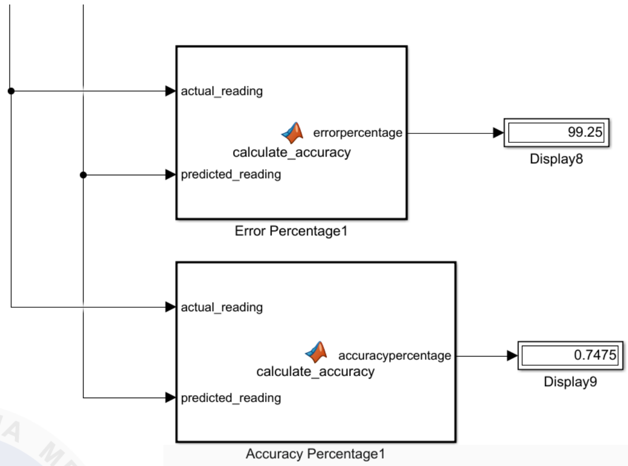

Figure 4.5 Accuracy and Error percentage before switching

Referring to Figure 4.5, the actual reading is the reading from the FSR data and predicted reading is the reading from the EMG signal before the switching method is performed. Each data is entered into the "MATLAB Function" block with the formula that has been set in formula (4.1) and (4.2). The reading on the percentage of error is very high before the switching method is used. The percentage of accuracy also shows a low value where the output is not good for use.

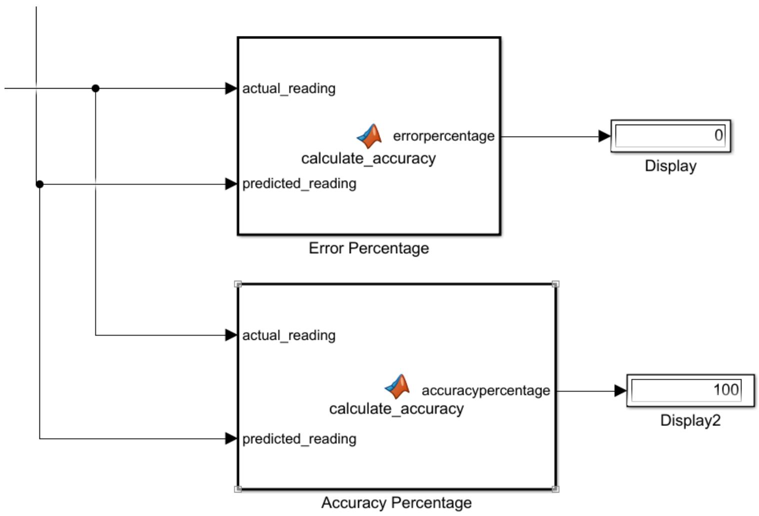

Figure 4.6 Accuracy and Error percentage after switching

Referring to Figure 4.6, The percentage error indication of 0% indicates that the switching method was successfully performed without any errors. No errors means that the signal from the actual reading was fully used during the switching process because the data from the predicted reading did not reach the "Compare-to-Constant" value that has been set. Next, the percentage of accuracy shows a value of 100% because the actual reading value after switching and before switching are the same because the predicted value does not meet the specified range conditions.

4.3 Summary

This chapter introduces a new switching methos that uses and FSR sensor to produce improved datasets, potentially replacing EMG signals for data collection. A case study demonstrates its effectiveness, referencing previous research from both Malaysia and other countries. The study validated the proposed methodology through controlled experiments involving subject, with results supported by theoretical understanding and experimental data. The method shows promise for generating more accurate datasets for specific applications.

The results highlight the FSR sensor's ability to provide clearer outputs compared to EMG signals. During testing, users performed tasks like holding objects within specified force ranges, with data automatically recorded in Excel. The switching method, implemented using Simulink, combines EMG and FSR data to improve accuracy. Before switching, significant errors and low accuracy were observed. After applying the method, errors were eliminated, and 100% accuracy was achieved, as the predicted FSR data replaced unreliable EMG readings. This demonstrates the method's capability to produce reliable datasets, confirming the utility in practical scenarios.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study explored the development of an innovative switching method that combines Force Sensitive Resistor (FSR) sensors with Electromyography (EMG) signals to improve data acquisition for analyzing hand movements, particularly for post-stroke rehabilitation. The research was driven by the limitations of conventional EMG signals, including high susceptibility to noise, signal distortion, and variability in results due to factors such as electrode positioning and individual physiological differences. By incorporating FSR sensors, this project demonstrated a practical and efficient solution to enhance the quality and reliability of muscle activity datasets.

The switching technique was meticulously designed and validated through a structured methodology, which involved the use of advanced hardware components such as Arduino Uno and FSR sensors, combined with software platforms like MATLAB and Simulink for data processing, simulation, and analysis. The integration of these technologies allowed for the simultaneous use of EMG and FSR datasets, ensuring that the strengths of each method were leveraged effectively. FSR sensors provided direct measurements of applied force and pressure, compensating for the inherent weaknesses of EMG signals. This hybrid approach not only improved signal clarity but also ensured more accurate representation of various hand movements, such as scissor grip, holding chopsticks, and thread manipulation.

The experimental results underscored the advantages of the proposed method. The combined use of FSR and EMG data produced output graphs that were easier to interpret, with minimal noise and distortion. This was evident in the detailed datasets generated for each predefined hand movement, which were recorded and visualized using tools like Excel and MATLAB. The accuracy of the switching method was further validated through neural network simulations, which quantified improvements in data precision and reduced error margins. By incorporating advanced computational models, this study bridged the gap between theoretical research and practical application, demonstrating the feasibility of the proposed method for real-world use.

One of the significant contributions of this research is its potential to enhance the design of assistive technologies, particularly in the field of rehabilitation engineering. For post-stroke patients, the ability to accurately monitor and analyze hand movements is critical for designing effective therapy regimes. The integration of FSR sensors addresses common challenges faced in traditional EMG-based systems, such as difficulties in detecting deep muscle activity and interference from motion artifacts. Additionally, the system's reliance on accessible and cost-effective components makes it a viable option for broader implementation, even in resource-limited settings.

Despite its success, the study also highlights areas for further exploration. The use of FSR sensors, while effective, is subject to certain limitations, such as non-linear response and sensitivity to environmental factors like temperature. Future research could focus on optimizing sensor design and calibration to overcome these challenges. Additionally, expanding the scope of the study to include a larger and more diverse sample population would provide insights into the system's adaptability and robustness across different use cases.

In conclusion, this project has successfully demonstrated a novel approach to addressing the limitations of EMG signal acquisition through the integration of FSR sensors. By leveraging the strengths of both technologies, the proposed method offers a more accurate, reliable, and cost-effective solution for analysing hand movements. This research lays a solid foundation for future advancements in assistive and rehabilitation technologies, with the goal of improving the quality of life for individuals recovering from stroke and other motor impairments.

5.2 Future Works

For future improvements, switching method results could be enhanced as follows:

i) To gain a more comprehensive understanding of hand movement, particularly in complex tasks requiring multi-joint coordination, future research could incorporate additional sensor.

ii) Developing robust calibration methods or utilizing new sensor materials to increase measurement accuracy and reliability.

iii) Use machine learning for enhanced signal processing.

iv) Expanded data collection, add more gestures or dynamic activities to the dataset.

v) Create means to tailor the system for each user, taking into consideration differences in hand size, muscle strength, and injury severity.

vi) Implementing real-time feedback systems, such as visual, aural, or haptic signals, may improve.

vii) Miniaturizing the technology and incorporating it into wearable devices.

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APPENDICES

Appendix A   Arduino Uno Source Code

```
// Define analog pins for 3 FSRs
const int fsrPins[3] = {A3, A4, A5};

// Calibration values for FSR sensors
const int fsrmin[3] = {220, 220, 220}; // Minimum raw value
const int fsrmax[3] = {1023, 1023, 1023}; // Maximum raw value

// Arrays to hold FSR values
int fsrValues[3];    // For FSR values (scaled 1-10)

// Scale range for FSRs
const int minScale = 0;
const int maxScale = 10;

void setup() {
  // Initialize serial communication with a higher baud rate
  Serial.begin(115200);
}

void loop() {
  const unsigned long duration = 10000; // Duration for data collection (10 seconds)
  unsigned long startTime = millis(); // Store the start time
  int dataCount = 0; // Counter for data points

  while (millis() - startTime < duration && dataCount < 1000) {
    int fsrSum = 0;  // Variable to store the sum of FSR sensor values

    // Read and map FSR sensor values
    for (int i = 0; i < 3; i++) {
      int fsrValue = analogRead(fsrPins[i]);
      fsrValues[i] = map(fsrValue, fsrmin[i], fsrmax[i], maxScale, minScale);
      fsrValues[i] = constrain(fsrValues[i], minScale, maxScale); // Constrain to valid range
      fsrSum += fsrValues[i]; // Add to FSR sensor sum
    }

    // Print the sum of FSR sensor values
    Serial.println(fsrSum); // Print sum of FSR sensors

    dataCount++; // Increment data point counter
```

```
    // Delay to maintain approximately 10 ms per sample
    delay(10);
  }

  // Stop execution by entering an infinite loop
  while (true) {
    // Keep the program idle
  }
}
```

Appendix B MATLAB Source Code

```
close all
clear all
clc

tic

%% Load data

fsr_data=xlsread('dataEMG.xlsx',1, 'a1:aa60001'); % load data dari excel utk 8 sample

scissor_train = fsr_data(1:10000, 1:2);
scissor_test = fsr_data(10001:15000, 1:2);

pen_train = fsr_data(15001:25000, 1:2);
pen_test = fsr_data(25001:30000, 1:2);

chopstick_train = fsr_data(30001:40000, 1:2);
chopstick_test = fsr_data(40001:45000, 1:2);

needle_train = fsr_data(45001:55000, 1:2);
needle_test = fsr_data(55001:60000, 1:2);

train_data = [scissor_train; pen_train; chopstick_train; needle_train];
test_data = [scissor_test; pen_test; chopstick_test; needle_test];


fsr_data=xlsread('FSRONLY.xlsx',1, 'a1:a10788'); % load data dari excel utk 8 sample

scissor_train_o = fsr_data(1:156, 1);
scissor_test_o = fsr_data(157:233, 1);

pen_train_o = fsr_data(2698:2853, 1);
pen_test_o = fsr_data(2855:2932, 1);

chopstick_train_o = fsr_data(5395:5550, 1);
chopstick_test_o = fsr_data(5552:5629, 1);

needle_train_o = fsr_data(8128:8283, 1);
needle_test_o = fsr_data(8285:8362, 1);

train_data_o = [scissor_train_o; pen_train_o; chopstick_train_o; needle_train_o];
test_data_o = [scissor_test_o; pen_test_o; chopstick_test_o; needle_test_o];

output_train = [scissor_train_o; pen_train_o; chopstick_train_o; needle_train_o];
output_test = [scissor_test_o; pen_test_o; chopstick_test_o; needle_test_o];
```

```
%% TRAINING INPUT DATA PREPARATION

feature_training=detrend(train_data);

%% Data segmentation: 50% overlap between windows

win_size =128;
win_inc =64;

%% Training data set

% Filtering

[b,a] = butter(1,[2 45]/500);        %right Fs/2       %% [a b]/c, where a and b are the band
bass edges, c is the nytwest rate Fs/2
feature_training = filtfilt(b,a,feature_training);

%% Training features

feature_training1= getfeature(feature_training,win_size,win_inc);

%% Normalised

i=1;
 for n=1:2;
   Anorm_training(:,n) = (feature_training1(:,i)-
min(feature_training1(:,i)))/(max(feature_training1(:,i))-min(feature_training1(:,i)));
   n=n+1;
   i=i+1;
 end
 %% TESTING INPUT DATA PREPARATION

feature_testing=detrend(test_data);

%% Data segmentation: 50% overlap between windows

win_size =128;
win_inc =64;

%% Training data set

% Filtering

[b,a] = butter(1,[2 45]/500);        %right Fs/2       %% [a b]/c, where a and b are the band
bass edges, c is the nytwest rate Fs/2
feature_testing = filtfilt(b,a,feature_testing);
```

```
%% Training features

feature_testing1= getfeature(feature_testing,win_size,win_inc);

%% Normalised

i=1;
 for n=1:2;
   Anorm_testing(:,n) = (feature_testing1(:,i)-
min(feature_testing1(:,i)))/(max(feature_testing1(:,i))-min(feature_testing1(:,i)));
   n=n+1;
   i=i+1;
 end

input_test_emg = timeseries(Anorm_training);save input_test_emg.mat -V7.3
input_test_emg
output_test = timeseries(test_data_o);save output_test.mat -V7.3 output_test
```