INVESTIGATION OF SITTING POSTURE IN CLASSROOM ENVIRONMENT

MUHAMMAD AMIR AFIQ BIN SUHAIMI

BACHELOR OF MECHATRONICS ENGINEERING

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

INVESTIGATION OF SITTING POSTURE IN CLASSROOM ENVIRONMENT

MUHAMMAD AMIR AFIQ BIN SUHAIMI

A report submitted in partial fulfillment of the requirement for the

Degree of Bachelor of Mechatronics Engineering

Faculty of Electrical Engineering

UNIVERSITY TECHNICAL MALAYSIA MELAKA

2017

I hereby declare that I have read through this report entitle "Investigation of Sitting Posture in Classroom Environment" and found it has compiled the partial fulfillment for awarding the degree of Bachelor of Mechatronics Engineering.

Signature : ……………………………….

Supervisor's Name : DR. AHMAD ZAKI BIN HJ. SHUKOR

Date : 15 JUNE 2017

I hereby declare that this report entitle *"Investigation of Sitting Posture in Classroom Environment"* is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

Signature : ……………………………………..

Student's Name : MUHAMMAD AMIR AFIQ BIN SUHAIMI

Date : 15 JUNE 2017

ACKNOWLEDGEMENTS

I would like to express my utmost gratitude to University Technical Malaysia Melaka (UTeM) for provide me an opportunity to pursue my Final Year Project for 1 semester to fulfill the requirements for the Bachelor of Mechatronics Engineering With Honors.

I am using this opportunity to express my deepest gratitude to Dr. Ahmad Zaki bin Haji Shukor for accepting me as one of his undergraduate researchers. I also would like to thank him again who in spite of being extraordinarily busy with his duties, took time out to hear, guide and keep me on the correct path and allowing me to carry out my Final Year Project 1 at the university. Besides, I also appreciate having Dr. Ahmad Zaki bin Haji Shukor as my supervisor because he supervising me throughout the period and was willingness to share some of his knowledge and experience to help complete my research.

Furthermore, I would also like to thank my family who has supported me physically and mentally throughout the time. Although their education is from another field, encouragement from them is very motivating for me to finish my research even with so many challenges.

ABSTRACT

Nowadays, there are many schools and universities around the world. As students increase, the teachers or the lecturers cannot give full commitment to their student's academic progress thus the students do not pay full attention while class in progress. Some studies have shown that one of the factors that affect the result of the students depends on their instructor and the other important factor that make students do not focus in class is based on their sitting posture. So, our objective of the experiment is to analyse sitting posture of the students by using force sensitive resistor sensor, to identify the suitable position of the sensor with minimum amount of sensors and to identify the relationship between student's sitting posture and focus in classroom environment. Four experiments had been done in Final Year Project 2. The first experiment, sensitivity of the Force Sensor were tested to ensure the Force Sensitive Resistor is in good performance. In the second experiment, four types of sitting postures which are back sitting posture, front sitting posture, right sitting posture and left sitting posture had been done. All type of sitting postures in objective 1 can be manipulated by using only 4 sensors. The technique used in objective 1 is implemented in objective 2. For the third experiment, 11 Force Sensors had been used and the suitable position of the Force Sensor had been fixed at the hipseat and the backseat. All type of sitting postures stated in objective 2 can be read and the efficiency of the prototype had been discussed. The last experiment is to relate students' sitting posture and their focus in classroom environment and 11 students had been participated. The results on the experiments had been translated into table and graph form. Overall data shows that by using only 11 Force Sensors, the determination of the conducted sitting posture is valid and can be used to relate the students sitting posture and focus.

ABSTRAK

Pada masa kini, terdapat banyak sekolah dan universiti di seluruh dunia. Bilangan pelajar semakin meningkat dan ini menyebabkan guru atau pensyarah tidak dapat memberi komitmen sepenuhnya terhadap pelajar-pelajar mereka. Hal ini menyebabkan pelajar tidak dapat menumpukan perhatian semasa kelas dijalankan. Beberapa kajian telah menunjukkan bahawa salah satu faktor yang mempengaruhi pelajar adalah daripada tenaga pengajar mereka dan faktor penting lain yang membuatkan pelajar tidak fokus di dalam kelas adalah berdasarkan posisi kedudukan mereka. Objektif projek ini adalah untuk menganalisis posisi kedudukan pelajar dengan menggunakan pengesan daya tekanan, mengenal pasti kedudukan pengesan yang sesuai dengan kuantiti yang sedikit dan akhir sekali untuk mengenal pasti hubung kait antara posisi kedudukan pelajar dan fokus semasa di dalam kelas. Empat eksperimen telah dijalankan dalam Projek Akhir Tahun 2. Eksperien pertama, kepekaan pengesan telah diuji untuk memastikan pengesan berada dalam keadaan yang baik. Eksperimen kedua, empat jenis posisi kedudukan telah dijalankan yang mana posisi belakang, posisi depan, posisi kanan dan posisi kiri. Semua jenis posisi kedudukan dalam objektif 1 boleh dibaca dengan menggunakan hanya 4 pengesan tekanan. Teknik yang digunakan dalam objektif 1 akan digunakan dalam objektif 2. Eksperimen ketiga, 11 pengesan tekanan telah digunakan dan kedudukan pengesan telah ditetapkan di tempat duduk bawah dan belakang. Semua jenis posisi yang dinyatakan dalam objektif 2 boleh dibaca dan kecekapan prototaip telah dibincangkan. Eksperimen terakhir adalah untuk mengaitkan di antara posisi kedudukan pelajar dan fokus mereka semasa di dalam kelas dan 11 orang pelajar telah mengambil bahagian dalam eksperimen tersebut. Hasil daripada eksperimen yang telah dijalankan, keputusan telah diterjemahkan ke dalam bentuk jadual dan graf. Data keseluruhan menunjukkan bahawa dengan menggunakan hanya 11 pengesan daya tekanan, penentuan posisi kedudukan yang dijalankan adalah sah dan boleh digunakan untuk mengaitkan posisi kedudukan pelajar dan fokus mereka.

TABLE OF CONTENT

CHAPTER	TITLE		PAGE
	ACKNOWLEDGEMENT		**i**
	ABSTRACT		**ii**
	ABSTRAK		**iii**
	TABLE OF CONTENTS		**iv**
	LIST OF TABLES		**ix**
	LIST OF FIGURES		**xi**
	LIST OF APPENDICES		**xvi**
1	**INTRODUCTION**		**1**
	1.1	Introduction of Project	1
	1.2	Motivation	2
	1.3	Problem Statement	3
	1.4	Research Objectives	4
	1.5	Scope	4
2	**LITERATURE REVIEW**		**5**
	2.1	Introduction	5

2.2	Real-Time Human Sitting Posture Detection Using Mobile Devices	6
2.3	Feasibility Study of Sitting Posture Monitoring Based on Piezo resistive Conductive Film- Based Flexible Force Sensor	10
2.4	Optimization of Sitting Posture Classification Based on user Identification	12
2.5	A New Approach for Readout of Resistive Sensor Arrays for Wearable Electronic Applications	14
2.6	Sitting Posture Diagnosis Using a Pressure Sensor Mat	18
2.7	Sensitive Cushion Based on Hetero-core Fiber Optics for Unconstraint Sitting Posture Monitoring.	20
2.8	eCushion: A Textile Pressure Sensor Array Design and Calibration for Sitting Posture Analysis	22
2.9	Sitting Posture Detection and Recognition Using Force Sensor	25
2.10	Robust, Low-cost, Non-intrusive Sensing and Recognition of Seated Postures	32
2.11	Summary of comparison	35
2.12	Summary of advantages and disadvantages	38
2.13	Comparison method used from previous studies	40
2.14	Conclusion	41

3	**METHODOLOGY**		**42**
	3.1	Introduction	42
	3.2	Project Flow Chart	43
	3.3	Component Selection	44
		3.3.1 Arduino Mega	45
		3.3.2 Force sensitive resistor sensor Module	46
	3.4	Overview of process and hardware	47
	3.5	Objectives Summary	48
	3.6	Algorithm of Sitting Posture (Objective 1)	49
		3.6.1 Experiment setup	50
		3.6.1.1 Sensitivity of the sensor	50
		3.6.2 Sitting posture experiment	52
		3.6.2.1 Pattern 1	52
		3.6.2.2 Pattern 2	52
	3.7	Project Flow Chart (Objective 2)	55
		3.7.1 Hardware	56
		3.7.1.1 Design 1	56
		3.7.1.2 Design 2	57
		3.7.2 Experiment setup	58
		3.7.2.1 Prototype validation test	58
	3.8	Sitting Posture and Focus Flow Chart (Objective 3)	60
		3.8.1 Experiment setup	61
		3.8.1.1 Sitting Posture and Focus investigation	61

4 RESULT AND DISCUSSION 63

4.2 Experimental Data (Objective 1) 64

4.2.1 Experimental Result for the sensitivity of the Force Sensor 64

4.2.1.1 Discussion based on the sensitivity of the Force Sensor 66

4.2.2 Experimental Result for Four Type of Sitting Posture 67

4.2.2.1 Discussion of Four Type of Sitting Posture 73

4.3 Experimental Data (Objective 2) 74

4.3.1 Experimental Result for the Best Position of the Force Sensor 74

4.3.2 Experimental Result for the Efficiency of the Prototype 79

4.3.3 Discussion of the Efficiency 89

4.4 Experimental Data (Objective 3) 90

4.4.1 Experimental Result for the relationship between sitting posture and focus of the students 90

44.2 Discussion of the Relationship between Sitting Postures and Focus of the students 92

5	**CONCLUSION & RECOMMENDATION**		**93**
	5.1	Conclusion	93
	5.2	Recommendation	94
	REFERENCES		**95**
	APPENDICES		**98**

LIST OF TABLES

TABLE	TITLE	PAGE
2.1	Categories of body size	6
1.2	Data of the participants	12
2.3	Comparison of Circuit Complexity among TDCA, MOAA, IMA and RMA for Readout of m×n sensor array on a Microcontroller based Wearable platform	14
2.4	Comparison of Error Sources among TDCA, MOAA, IMA and RMA	15
2.5	Pressure sensor mat specification	18
2.6	Result Precision vs Recall	24
2.7	List of criteria from previous studies	35
2.8	Advantages and Disadvantages from previous study	38
3.1	Specification feature of Arduino Mega	45
3.2	Specification feature of Force Sensing Resistor Module	46
3.3	Overview of the process and hardware	47
3.4	Component of prototype design 1	57
3.5	Component of prototype design 2	57
4.1	Measurement detail for prototype objective 1	67

4.2	Back sitting posture	68
4.3	Front sitting posture	69
4.4	Right sitting posture	70
4.5	Left sitting posture	71
4.6	Overall Result for objective 1	72
4.7	Measurement Detail for prototype objective 2	76
4.8	Result of Multiple Choice question	90

LIST OF FIGURES

FIGURE	TITLE	PAGE
1.1	(a) Sitting Posture = 90°. (b) Sitting Posture > 90°. (c) Sitting Posture < 90°	3
2.1	The android application of the human information	7
2.2	The windows-based server side application	7
2.3	Data Gathering Tool	8
2.4	Model performance in terms of Accuracy	9
2.5	Model Performance in terms of Kappa Statistic	9
2.6	Force-voltage characteristic of proposed sensor. Develop force sensor shows the power-law characteristic	10
2.7	Ratio of mean pressure distribution in the front row to that in the back row of the sensor array	11
2.8	Seated postures used in the experiments and their respective class label: (P1) seated upright, (P2) leaning forward, (P3) leaning back, (P4) leaning back with no lumbar support, (P5) leaning left, (P6) leaning right, (P7) right leg crossed, (P8) right leg crossed, leaning left, (P9) left leg crossed, (P10) left leg crossed, leaning right, (P11) left leg over right,	13

(P12) right leg over left.

2.9 The result of the user in smartphone when perform sitting posture 13

2.10 Prototype of a 10 × 10 textile resistive pressure sensor array and DAQ unit (Upper right: an enlarged view of the DAQ unit). 16

2.11 Pressure mapping results by 10×10 textile resistive sensor array (the sensing cushion) using RMA: three sitting postures of (a) sit-up, (b)backward, (c) forward and the corresponding mapping results shown in (d), (e), and (f), respectively. 17

2.12 Chair with two pressure sensor mats 18

2.13 Difference of 'correct posture' distribution between two people 19

2.14 Experimental setup for measuring force property of sensitive cushion 20

2.15 Structure of sensitive cushion 21

2.16 Apparatus for measuring of position with sensitive cushion 21

2.17 Real-time responses of subject moving on the chair with two moving patterns, (a) pattern-1, (b) pattern-2, (c) second trial of pattern-2 21

2.18 The prototype of smart cushion 23

2.19 Sensor thickness 23

2.20 Proper sitting posture of type 1 25

2.21 Proper sitting posture of type 2 26

2.22	Improper sitting posture of crossing legs type 1	26
2.23	Improper sitting posture of crossing legs type 2	26
2.24	Crooked sitting posture	27
2.25	The cushion and positions of the sensor	27
2.26	Sensors values of Proper sitting posture of type 1	28
2.27	Sensors values of proper sitting posture of type 2	28
2.28	Sensors values of crossing legs type 1(a)	29
2.29	Sensors values of crossing legs type 1(b)	29
2.30	Sensors values of crossing legs type 2(a)	30
2.31	Sensors values of crossing legs type 2(b)	30
2.32	Sensors values of crooked sitting posture type (a)	31
2.33	Sensors values of crooked sitting posture (b)	31
2.34	Left is the Tekscan ConforMat system (2048 sensors) and on the right is our deployed system (19 sensors) installed on the same model of chair	32
2.35	Method to develop a low cost, robust and fast learning system for recognizing the classes with high-dimensional data.	33
2.36	The order of the sensor on the chair (19 sensors)	33
2.37	Best results were obtained by using 31 sensors (87% accuracy), while by using 19 sensors produce same accuracy (82%) as 4032 sensors do.	34
3.1	Overview of overall project flow	43
3.2	Arduino Mega	45

3.3	Force Sensing Resistor sensor Module	46
3.4	Objectives Summary	48
3.5	Flow chart of Sitting Posture Algorithm	49
3.6	Pattern 1 (Right and Left position)	52
3.7	Pattern 2 (reclining and stooping position)	52
3.8	Position of the sensor at the chair Front;1, Right;2, Left;3, Behind;4	53
3.9	Flow Chart of position sensor	56
3.10	Design 1	56
3.11	Design 2	57
3.12	Flow Chart of investigation of the relationship between sitting posture and focus of the students	60
4.1	Connection of the sensor	64
4.2	Serial monitor	65
4.3	Graph of the sensitivity of the Force Sensitive Resistor	66
4.4	Prototype of objective 1	67
4.5	(a): Back sitting posture. (b): Right sitting posture. (c): Left sitting posture. (d) Front sitting posture.	68
4.6	Result of Back Sitting Posture	69
4.7	Result of Front Sitting Posture	70
4.8	Result of Right Sitting Posture	71
4.9	Result of Left Sitting Posture	72
4.10	Initial position of the force sensor	75

4.11	Final position of the Force Sensor	75
4.12	Connection of the completed Force Sensor	76
4.13	Prototype of the project	77
4.14	14 (a): Leaning Back. (b): Sitting Upright. (c): Leaning Forward. (d) Leaning Right. (e): Leaning Left. (f): Right leg Crossed. (g): Left Leg Crossed. (h) Slouching	78
4.15	Subject (42 Kilogram)	79
4.16	Subject (50 Kilogram)	80
4.17	Subject (60 Kilogram)	80
4.18	Subject (61 (Kilogram)	81
4.19	Subject (65 Kilogram)	81
4.20	Subject (78 Kilogram)	82
4.21	Leaning Back Sitting Posture	84
4.22	Sitting Upright Sitting Posture	84
4.23	Leaning Forward Sitting Posture	85
4.24	Leaning Right Sitting Posture	85
4.25	Leaning Left Sitting Posture	86
4.26	Right Leg Crossed Sitting Posture	86
4.27	Left Leg Crossed Sitting Posture	87
4.28	Slouching Sitting Posture	87
4.29	Prototype's Efficiency	89
4.30	Relation between type of Sitting Posture and Focus	92

LIST OF APPENDICES

APPENDIX	TITLE	PAGES
A	Gantt Chart for FYP1	98
B	Gantt Chart for FYP2	99
C	Coding (Objective 1)	100
D	Coding (Ojective 2)	102

CHAPTER 1

INTRODUCTION

1.1 Introduction of Project

Sitting is one of the normal behaviour that everyone will do in their daily life. Students especially spend more time sitting while studying in classroom. Some studies have shown that sitting posture is the most important element to get focus while studying. There are many bad side effects that will hit students due to poor prolonged posture such as neck and low back pain and others. If these conditions persist, students may face many medical ailments that may affect their present and also future life. Illness which comes from bad sitting posture also will disturb the students to focus on studies in classroom and without conscious it will affect the students result and their life afterwards. So to prevent the problems, students must pay full attention while learning in class and one of the main problems to get focus in the class is how the sitting posture of the students. This issue will become more serious if the students do not change their sitting posture lifestyle. Many experiments and studies about the sitting posture have been conducted before. Hence this study is to identify the relationship of the student's sitting posture and focus in classroom environment.

1.2 Motivation

Nowadays, there are many school and university that have been opened. The number of students are increase overtime. This phenomenon will make the instructors cannot focus to their students even in class environment. As a result, students become more aggressive to do what they feel right. During the class, most students cannot pay full attentions to the lecturer's talk. So, the investigation has been conducted to find out the reasons of why the students cannot fully focus while studying in class. One of the main factors is coming from the behaviour of the student's themselves like how the position of the students while sitting in class. Students spend most of their time with studying in class, doing assignment in front of their laptop or studying for their examination while sitting. From the research that had been conducted before, almost every students have a bad sitting posture in classroom. From the research that have been conducted by McKinley Health Centre (2008), extended time of sitting while doing activities will make soft tissue and muscles will become shortened or known as stretched from normal [13]. Therefore it will disturb the students to focus in studying. According to Hojat and Mahdi (2011) [12], they state 57% of the students spend their time seated in a kyphotic position or in leaning forward position while 43% of them in a slouching position. Those two type of sitting postures are the basic things that the student will do during study in class. If the students still do not improve their sitting posture, it will give an impact to their focus. Therefore, the purpose of this study is to analyse and identify the sitting posture of students to their focus.

1.3 Problem Statement

The number of students increase every year. Many schools and universities were built to give educational to the students but the number of teacher and lecturer still not enough to oversee every each of their students. Therefore, some of the students are take this chance as the opportunity to play around or sleep during the class and some of them trying to be focus during studying but their sitting posture makes them feel uncomfortable thus interrupt them to fully focus. Students have failed to notice that the sitting posture is the important part to stay focus while learning. To stay focus while studying, research about sitting posture has been done and to investigate about the sitting posture by using existing smart chair, it will use a lot of cost. Therefore, this research also will study about how to create the low cost prototype to investigate the student's sitting posture. To create the low cost prototype, there are some issues that arise in this research. First, what is the minimum amount of force sensor will be used and where is the best position to put the sensor? Second, what type of sitting postures affect student's focus in classroom? These are the basic type of sitting posture that most of the students do during the class which are normal sitting posture (figure 1.1(a)), leaning forward position (figure 1.1(b)) and leaning backward (figure 1.1(c)). Most of the studies show that the correct sitting posture must be followed by the students are 90° to the seat as shown in figure 1.1(a). While the people that sit more than 90° (figure 1.1(b)) or less than 90° (figure 1.1(c)) are the bad sitting postures and the probability to get focus is lower than normal sitting posture as shown in figure 1.1(a). The early experiment will be done by using Force Sensitive Resistor sensor to study about the basic type of sitting posture before proceed to the next important experiment.

(a) (b) (c)

Figure 1.1: (a) Sitting Posture = 90°. (b) Sitting Posture > 90°. (c) Sitting Posture < 90°

1.4 Research Objectives

The objectives of the research are:

1. To analyse sitting posture of the students by using force sensitive resistor sensor.
2. To identify the suitable position of the sensor with minimum amount of sensors.
3. To identify the relationship between student's sitting posture and focus in classroom environment.

1.5 Scope

The scopes of the research are:

1. The Force Sensitive Resistor is used to detect the sitting posture of the students.
2. The Force Sensitive Resistor sensor is place at hipseat and backseat.
3. The Force Sensitive Resistor only apply on student's chair (UTeM).
4. Objective 1 and 2 will be conduct outside of the classroom.
5. Investigation of sitting posture for objective 3 will be conduct in classroom environment.
6. Arduino Mega is used as microcontroller to control the sensor.
7. The experiment for objective 3 is test with different student.
8. Prototype for the students with 40 Kilogram to 80 Kilogram.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, the main point will be discussed based on every journal that had been read with the advantages and disadvantages of sitting posture. Other than that, comparison of criteria of the sitting posture also will be described in this chapter.

2.2 Real-Time Human Sitting Posture Detection Using Mobile Devices

According to [1], the objective of the product is to develop an acceptable model to detect proper and improper sitting posture using gyroscope. There are some issues arise about the Real-Time Human Sitting Posture Detection system such as the durability, measurement for flexion exercise are limited and the main problem is user must be connected to a PC. So to ease the patients, new development of the Real-Time Human Sitting Posture Detection is created by Using Mobile Devices.

So, BITAIKA system has been developed and it gives visually understandable to its users [56]. The posture of the human is controlled by Kinect and Piezoelectric sensors. Function of the Kinect sensor is captures the person's lateral image and detect the head middle position of the body. All the information will be send to the computer as a result of the sensor. The computer will give notification to the user with message that pop up at the screen.

Forty nine (49) students from Valenzuela City, Philippine were participated in our experiment. Thirty (30) female and nineteen (19) male with different body fames are involved as shown in table 2.1.

Table 2.1: Categories of body size

Gender	Height	Wrist Size	Category	No. of Participants
Female	5' 2" or less tall	< 5.5"	Small	5
		5.5" to 5.75"	Medium	5
		> 5.75"	Large	5
Female	5' 2" to 5' 5" tall	< 6"	Small	5
		6" to 6.25 "	Medium	5
		> 6.25"	Large	5
Male	5'5" or less tall	< 6"	Small	2
		6" to 6.25 "	Medium	1
		> 6.25"	Large	1
Male	taller than 5' 5"	<6.25"	Small	5
		6.25" to 6.5"	Medium	5
		>6.5"	Large	5

To gather the information, versatile application for Android cell phones is built up with gyro sensors (Fig. 1). This was composed in Android Studio 1.3.2, outlined particularly to read the inclination (in degrees) of the three (3) human spinal focuses which is thoracic, thoraco-lumbar and lumbar.

Figure 2.1: The android application of the human information

Windows-based application as shown in figure 2.2 was developed on the server side (our laptop) which was used to record and capture the readings on the smartphones.

Figure 2.2: The windows-based server side application

Last part of gathering the data is with customized an adjustable girdle as shown in figure 2.3. This is because to assure mobile devices is in contact with three spinal points.

Figure 2.3: Data Gathering Tool

The data was taken with the information of name, age, gender, height, wrist size and weight, and computed body mass index (BMI). The participants need to wear the customized girdle with smartphone in it. Besides, the participants also need to turn on the mobile application to read the data. Nine proper and improper sitting was captured.

With using a Rapid Miner device, demonstrate improvement was led via preparing a few classifiers utilized by past concentrates, for example, KNN, SVM, and MLP, in addition to an outstanding classifier that can deal with some ostensible traits and an ostensible class called Decision Tree. We additionally set the classifiers to utilize the Batch-Cross Fold Validation to accept the models. The subsequent general exhibitions of the models as far as exactness rate and kappa measurement are introduced in Figure 2.4 and Figure 2.5, individually.

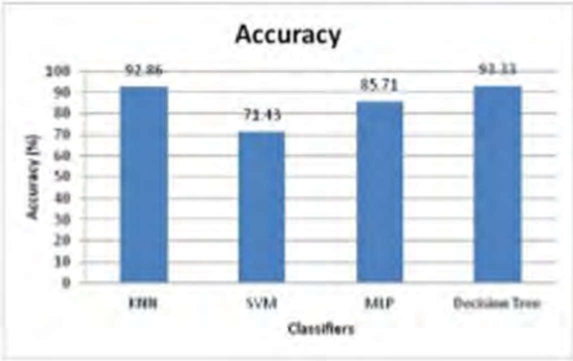


Figure 2.4: Model performance in terms of Accuracy

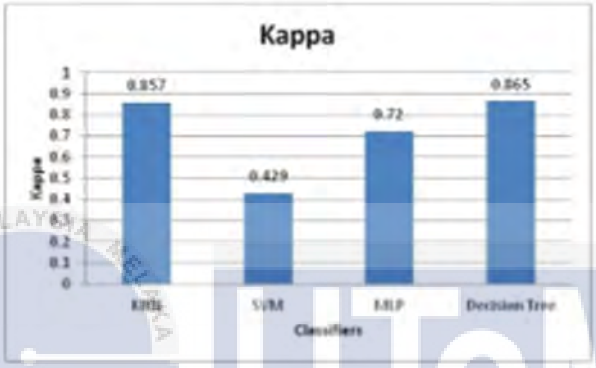


Figure 2.5: Model Performance in terms of Kappa Statistic

Figures 2.4 and 2.5 demonstrate that the Decision tree classifier gave the best model execution with a precision rate of 93.33 and kappa measurement of 0.865 when using gain ratio attribute criterion, a maximal profundity of 10, a certainty of 0.25, a minimal gain of 0.1 and insignificant leaf size of 2.

2.3 Feasibility Study of Sitting Posture Monitoring Based on Piezoresistive Conductive Film- Based Flexible Force Sensor

According to [2], the aims of this study is to create a novel force sensor using a type of piezoresistive polymer film, and to confirm the practicality of identifying improper sitting postures using force sensor platform.

The sensing platform developed in this study had a structure similar with that described in [8]. This structure delivers output depending on the applied force, according to the piezoresistive characteristic of the Velostat film. A Velostat is a conductive film with a volume resistivity of less than 500 ohm·cm, a thickness of 104 µm, a flexural modulus of 40,000–50,000 psi, and a tensile strength of 1,700–2,000 psi.

$$V_{OUT} = \frac{R_{VFS}}{R_M + R_{VFS}} V_+$$

To determine the force–resistance characteristics of the sensor, we investigated the output voltage (V_{out}) change by increasing the number of weights applied to the sensor in increments of 1 kg, using 1-kg weights 7 cm in diameter. To confirm the repeatability of the results, the test was repeated ten times. The average output voltage changed from 4.5 V to 0.5 V as the load was increased from 0 to 10 kg. When the weight was increased by 1 kg, the voltage decreased according to the following power law: $y = 4.985x^{-0.9064} - 0.1415$, $R^2 = 0.999$, RMSE = 0.0173. This power law is illustrated in figure 2.6.

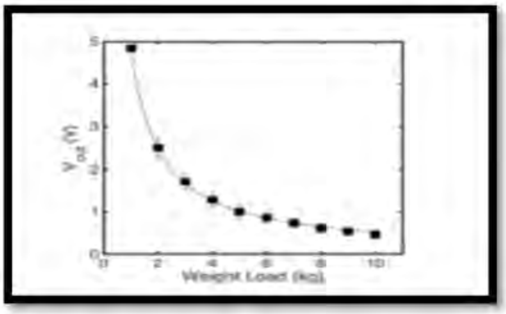


Figure 2.6: Force-voltage characteristic of proposed sensor. Develop force sensor shows the power-law characteristic

To test the feasibility of measuring the force distribution, three-by-three sensor array has been developed. Data were recorded during the experiment from the sensor at 100-Hz sampling frequency. It is only three postures that can be measured through this experiment. Seven participants have been involved which is two males and five females. In the trial, the force distribution was measured for each of the three postures for 10 s, and this was repeated ten times. Figure 2.7 show the ratio of the average pressure measured at the front row to that at the rear row of the sensor array. The front–back ratio (F/B ratio) is the ratio of the average front-side voltage output to the average back-side voltage output, was 0.605, 0.248, and 2.333 for the UP, FL, and BL postures, respectively. These results indicate that the pressure is concentrated in the middle part of the thighs in the FL posture, whereas the pressure is concentrated on the buttocks in the BL posture.

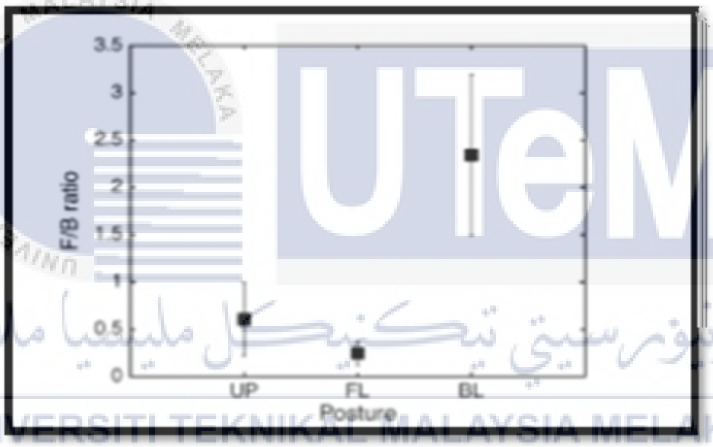


Figure 2.7: Ratio of mean pressure distribution in the front row to that in the back row of the sensor array

The result of this experiment show that the sensor array can discriminate between the BL and other postures but UP and FL postures is not be able to distinguish by the sensing platform. The other disadvantages are the resolutions and measurement area are not enough high and need to be increase. The position and size of the sensor also need to be determined to optimize the sensor platform.

2.4 Optimization of Sitting Posture Classification Based on user Identification

According to [3], the objectives of this study is to make the users alert of their improper sitting posture. First prototype was built by using 8 pneumatic bladders (4 air bladders at the backrest and 4 bladders at the chair seat) and it is connected to piezoelectric sensor. It is only limited to 11 postures and the classification score is 80%.

After the development of first prototype, the new model has been built due to the limitation of the first prototype and the classification score show 89.0% increase 9% from the first prototype. New feature like vacuum pump was introduced to control the pressure inside the bladder to get better performance. Raspberry Pi is used in this experiment to control chair's instrumentation and it can be connected with Bluetooth to communicate with smartphone. Android application was developed to give the information about the sitting posture to the user.

To run the experiment, the data of the users must be collected as shown in table 2.2. 12 sitting postures were acted by the participants with each posture for 20 seconds. The frequency used is 8Hz and took 100 time points (12.5 seconds out of 20 for each sitting posture). The experiment was repeated 3 times to get average result. Figure 2.8 shows the type of sitting posture.

Table 2.2: Data of the participants

Information About the Participants	***Values***
Number of Subjects (M/F)	50 (25/25)
Age (years) [a]	26,4±9,5
Weight (Kg) [a]	66,8±12,8
Height (cm) [a]	170,5±9,8

Figure 2.8: Seated postures used in the experiments and their respective class label: (P1) seated upright, (P2) leaning forward, (P3) leaning back, (P4) leaning back with no lumbar support, (P5) leaning left, (P6) leaning right, (P7) right leg crossed, (P8) right leg crossed, leaning left, (P9) left leg crossed, (P10) left leg crossed, leaning right, (P11) left leg over right, (P12) right leg over left.

Figure 2.9 shows the system at the smartphone and this application is to make the user access to their habits of sitting posture.

Figure 2.9: The result of the user in smartphone when perform sitting posture.

2.5 A New Approach for Readout of Resistive Sensor Arrays for Wearable Electronic Applications

According to the [4], there are many ways to readout strategies for resistive sensor arrays such as transistor/diode controlled approach (TDCA), incidence matrix approach (IMA) and multiplexer and op-amp assisted approach (MOAA). Due to some problems that need to be handled, a new method has been proposed which is resistance matrix approach (RMA). This is because to make the circuit low complexity, low crosstalk error, satisfactory accuracy and sufficient sensor capacity. The experiment is only need microcontroller and resistors. However, to eliminate crosstalk currents between sensors, additional electrical component like transistor must be added and it makes the circuit increase in complexity which may influence the effectiveness of the resistive sensor. Additional transistor is important in controlling sensing pixel's switching state to get better result with avoid crosstalk. Table 2.3 gives a comparison about a circuit complexity between TDCA, MOAA, IMA and RMA on a microcontroller based wearable platform.

Table 2.3: Comparison of Circuit Complexity among TDCA, MOAA, IMA and RMA for Readout of m×n sensor array on a Microcontroller based Wearable platform

Approach	Number of required electrical components							Complexity ranking[1]
	Microcontroller /Control circuit	External ADC	Multiplexer /Switch	Op-amp	Transistor	Current source	Resistor	
TDCA	1 (including on-chips resources of embedded ADCs and I/O ports)	0	0	0	$m \times n$	0	n	Medium
MOAA		0	Several[2]	Several	0	0	m	High
IMA		Several[3]	Several[4]	0	0	Several	0	High
RMA		0	0	0	0	0	n	Low

Every ways to approach for readout of Resistive Sensor has their error source and how it minimized the error. Table 2.4 below shows comparison of error sources among TDCA, MOAA, IMA AND RMA.

Table 2.4: Comparison of Error Sources among TDCA, MOAA,IMA and RMA

Approach	Crosstalk error	Error sources
TDCA	Crosstalk currents can be eliminated by transistors. Crosstalk errors are very small.	Errors are caused by low precision of ADCs, and on-resistance of the transistor/diode, as the measured resistance is a sum of the sensor's resistance and transistor/diode's on-resistance.
MOAA	Crosstalk currents are minimized by control of additional chips. Crosstalk errors can be very small under optimal circuit configurations.	Errors are caused by non-ideality of op-amps, multiplexers' cross leakage currents and on-resistances of switches and multiplexers, low precision of ADCs.
IMA	Although crosstalk currents are allowed, sensor resistances can be calculated accurately.	Errors are caused by low precision of ADCs and current sources, and inadequate scanning rate.
RMA	Although crosstalk currents are allowed, sensor resistances can be solved accurately.	Errors are caused by low precision of ADCs and reference standard resistances, and inadequate scanning rate.

After make some investigation, implementation of RMA on prototype had begun and the experimental results was out. 10×10 textile resistive sensor array with sensor size: 10 × 16 × 3mm has been built. 20 electrical wires of a ribbon cable is used to interface sensor array with DAQ (Data Acquisition) unit. Bluetooth module is use for data transmission and 170mAh Li-ion battery isuse as power supply. As we know, resistors 4.7k and 11.7k were used as reference resistor. ADCs function is to digitized the data and then wirelessly transmitted the data via Bluetooth to a remote computer. This digitized data will be established in remote computer and solve the sensor resistance. After that, resistance data is converted to pressure data and all the information is stored by smart cushion software in computer. Below shows the figure of prototype of a 10 × 10 textile resistive pressure sensor array and DAQ unit (upper right: an enlarged view of the DAQ unit).

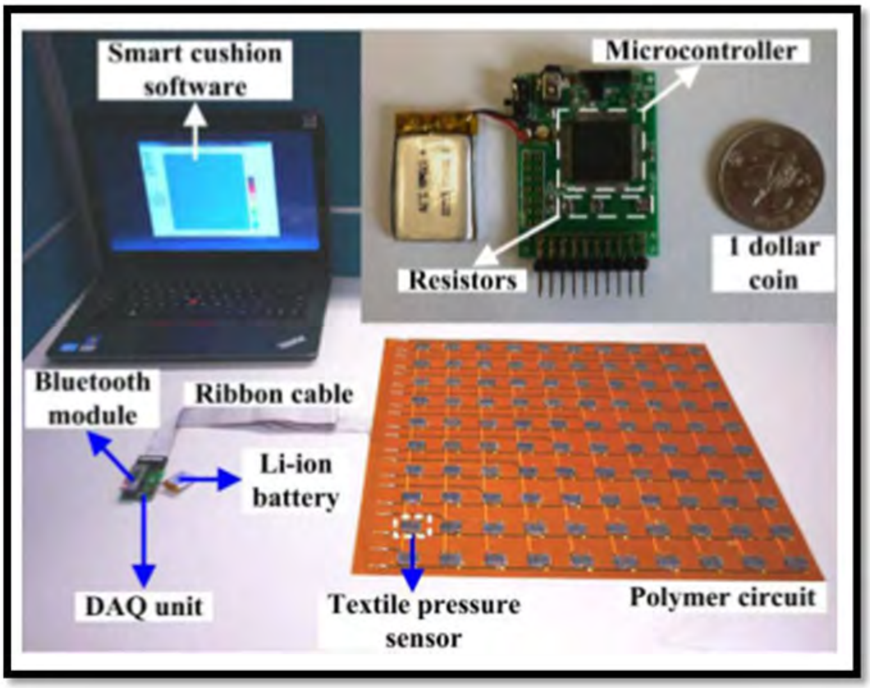


Figure 2.10: Prototype of a 10 × 10 textile resistive pressure sensor array and DAQ unit (upper right: an enlarged view of the DAQ unit).

One sensor is taken out from 100 and ten tests were conducted for the first trial. For the second trial, another ten test were conducted with two standard weight by 2 sensors randomly taken out from 100 sensors. To make sure that there is no crosstalk error, another ten test were conducted in same row or column and this row and column is randomly selected. RMA measured the resistance of the 100 sensors and for every each test, it has been recorded in computer. 30 tests were conducted and every test last for 20 seconds. The loading occurred from 11-13 seconds by removing the block and it lasted until it reach 20 seconds. Below shows the result of pressure mapping of the posture by the student.

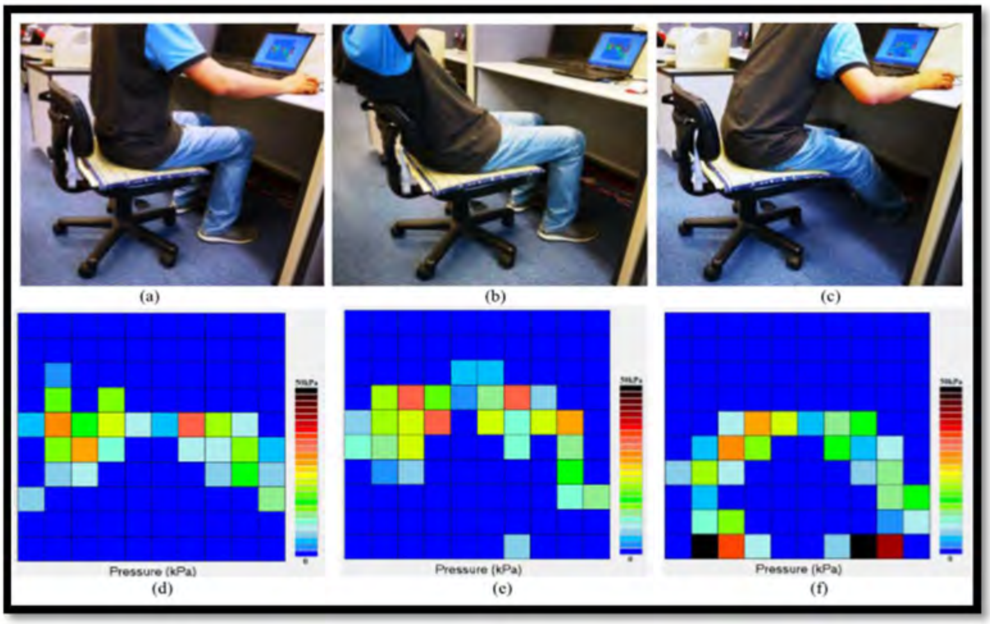


Figure 2.11: Pressure mapping results by 10×10 textile resistive sensor array (the sensing cushion) using RMA: three sitting postures of (a) sit-up, (b)backward, (c) forward and the corresponding mapping results shown in (d), (e), and (f), respectively.

To conclude, this paper has showed another new approach for readout of sensor array, named RMA, which solving matrix equation to identify sensor resistance. A comparison of three existing approaches, IMA, TDCA, and MOAA, has been presented in terms of the sensor capacity, circuit complexity and measurement error. Overall show that RMA circuit is low complexity, low crosstalk error, satisfactory accuracy and sufficient sensor capacity which is appropriate for applications that request low complexity circuits such as protective wear, work wear, rehabilitation, wearable electronics for health monitoring, sports training and so on.

2.6 Sitting Posture Diagnosis Using a Pressure Sensor Mat

According to [5], it measure the sitting posture of the human based on how often he changes the posture and what degrees the subject change the posture. The system that will be built is usable, simple and has not been proposed yet. This experiment was carried out with asked the subject to sit in a good posture for a given time according to the paper instruction.

The equipment that has been used is Force Sensitive Application. Two pressure sensor mats was put on the main seat which are hipseat and backseat. The force at the backseat is to make people learn on how to use the backseat while they are working at desk. Figure 2.12 shows the chair with two pressure sensor mats and table 2.5 shows the specification of pressure sensor mat.

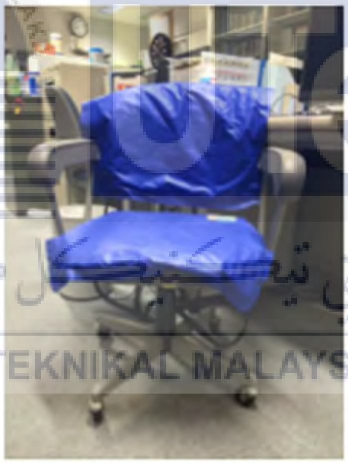


Figure 2.12: Chair with two pressure sensor mats

Table 2.5: pressure sensor mat specification

Table 1: Pressure sensor mat specifications

Measurable mat area	33×33[cm]
Measurable range	0-200[mmHg]
The numeber of sensors	256 (=16×16)
Sensor size	17.5×17.5[mm]
Sensor space	3.3×3.3[mm]

Four sitting posture has been carry out in this experiment which are F(lean forward), R(lean rightward), L(lean leftward), (lean backward). 256 sensors were used. The data was collected from the people who are in good sitting posture and at the beginning the test is repeated person by person. The result of pressure mapping at the beginning stage of two model of sitting posture can be seen in figure 2.13.

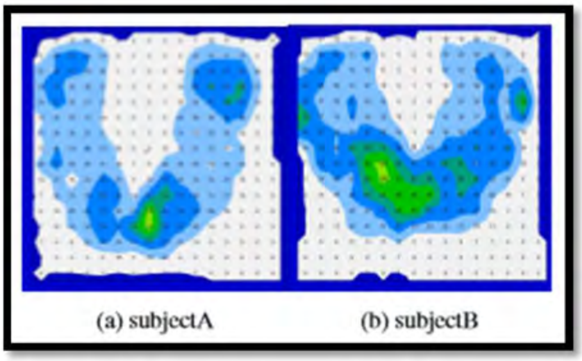


Figure 2.13: Difference of 'correct posture' distribution between two people

In this experiment, its only focus on three measures which are the mean moving distance, amount of distance from the center of correct posture and number of times the point jumps outside and goes back again to the center region.

The experiment had been carried out with two subjects who are both male university students with the range of the weight 60-65kg. The video of the experiment also was recorded for evaluation. The frequency has been set to 2Hz. The experiment is begin with the subject sit with correct posture for 30 seconds. The subject is allowed to do anything he likes for an hour to three hours. Subject is permitted to leave the chair with minimal time. After three hours, the experiment is done.

To conclude, effectiveness of this system is hard to evaluate. The new method (pressure sensor chair) have been developed to quantify the correct sitting posture apart from wrong sitting posture. For the coming experiment, backseat pressure mat will be develop and the effectiveness of the system will be tested for real diagnosis.

2.7 Sensitive Cushion Based on Hetero-core Fiber Optics for Unconstraint Sitting Posture Monitoring.

In [6], it propose a sensitive cushion based on hetero-core fiber optic bending sensor which has single-mode transmission line. Hetero-core fiber sensor has high signal to noise ratio to bending action. An experimental setup as shown in figure 2.14 is consisted of LED-PD which function as measure the optical loss of hetero-core fiber in real time. PC was used to measure optical loss through an A/D converter at frequency 10-Hz.

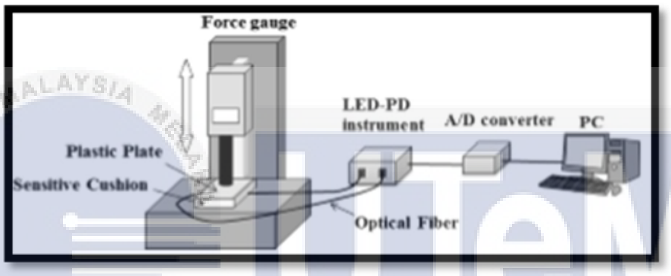


Figure 2.14: Experimental setup for measuring force property of sensitive cushion

Hetero-core fiber optic sensors were installed in the cushion with 10 mm depth by the upper surface of the cushion. The sensor is placed as shown in figure 2.15. The movement of the body can be detected by the sensor in any direction. Two moving patterns were tested on subjects. Figure 2.16 shows the apparatus for measuring of position with sensitive cushion. Pattern 1 is right-left while pattern 2 is stooping-reclining. Pattern 2 is tested for the second time to get the accurate result.

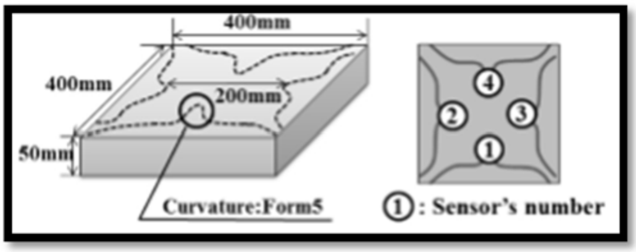
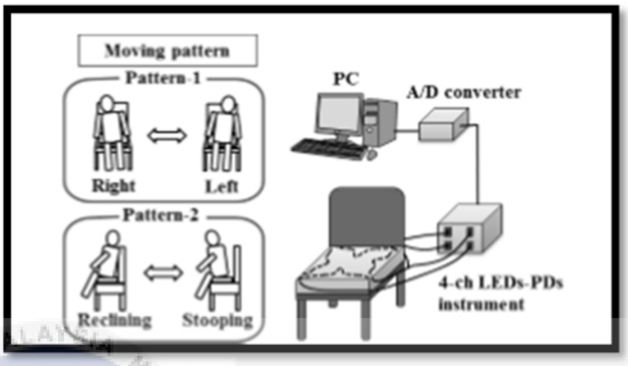


Figure 2.15: Structure of sensitive cushion



. Figure 2.16: Apparatus for measuring of position with sensitive cushion

Figure 8 show the result of the experiment. The reading of the optical loss sensor will increase when it does not get hit by any object and the reading will decrease when the subject touch the sensor. Figure 2.17(a) shows result for pattern 1 while figure 2.17(b) shows result for pattern 2 and figure 2.17(c) show result of repeated pattern 2.

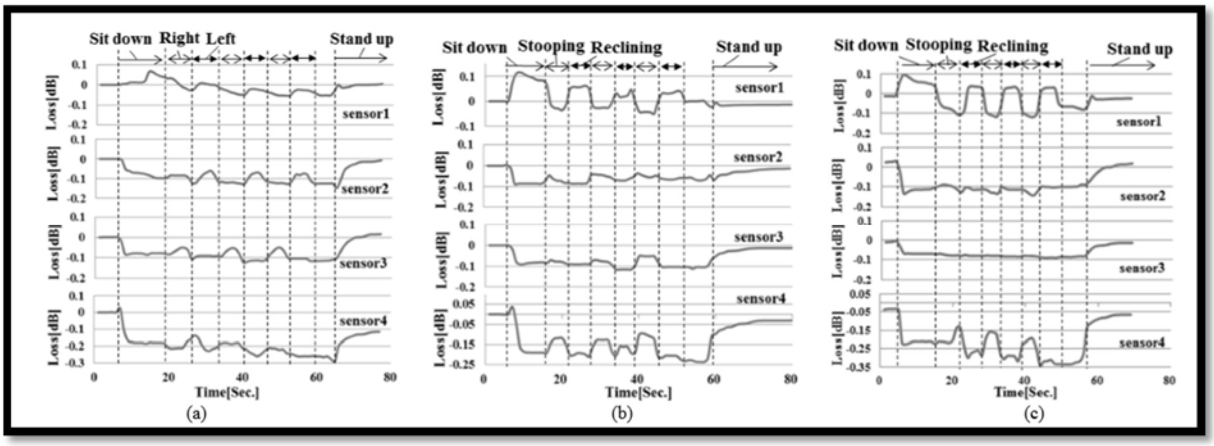


Figure 2.17: Real-time responses of subject moving on the chair with two moving patterns, (a) pattern-1, (b) pattern-2, (c) second trial of pattern-2

2.8 eCushion: A Textile Pressure Sensor Array Design and Calibration for Sitting Posture Analysis

In [7], electrical textile or known as eTextile, is a composite yarn that made up of fibers which is coated with conductive polymer. Etextile is much more economical price and comfortable touch feeling than silicon or piezoelectric based sensors [22], [23]. Normally, a textile sensor having a problem with the environmental noise, offset, scaling and crosstalk. Due to the instable factors, it will affect the result of the sensor reading and it will produce error result. This problem is more serious if it is integrated into clothes or other facilities. For example, in sitting position, pressure distribution is not only read the subject position but its also depends on other factors such as weight, body size and sitting orientation.

To increase the efficiency of the product, a new model has been proposed and textile sensor has been build to be tested. Before the new model is created, the smart cushion had been tested with14 subjects and the results show some major issues such as scaling, offset, back ground noise and cross talking. Next, efficient algorithm for the new model also has been presented for sitting posture recognition. The result show the recognition of sitting posture can reach 85.9%.

The system use in the product is composed of three components: textile sensor array, data sampling unit and data center. Figure 2.18 shows the implementation of the textile sensor array in Smart Cushion. The total sensor surface area is 10 by 10 inch, where the area of each square sensor is 5/8 by 5 /8 inch as each row and column bus is 5/8 inch wide, and the space between sensors is 1/8 inch. The data sampling unit is designed based on arduino board. The frequency of the smart cushion is set to 10 Hz..

Figure 2.18: The prototype of smart cushion

Sensor array architecture is the important part to get better performance of smart cushion. The smart cushion use three-stacked-layer structure to build the sensors, where the middle layer is eTextile. The benefit of this structure is that the top layer and the base layer are ordinary texture consistently covered with parallel conductive buses. Both of the top and bottom layer are coated with the 16 buses. Therefore, 256 sensors is needed to put on the sheet. Figure 2.19 shows the sensor thickness which is only 1.5mm.

Figure 2.19: Sensor thickness

After testing the textile sensor with the first model, some algorithm has been applied to increase the efficiency of the smart cushion. So, the experimental was setup at campus. 25 subjects have involved in the experiments, including 15 males and 10 females. Seven posture must be done by students which are situp, forward, backward, right lean, left lean, left foot over right and right foot over left. The proposed algorithm make the result show 85.9% accuracy for overall sitting posture which is outperform from the previous smart cushion (79%). Table 2.6 show the results of the experimental and for the situp, forward and backward show that these 3 postures share many common feature.

Table 2.6: Result Precision vs Recall

	Situp	Forward	Backward	LL	RL	LFOR	RFOL	Total	Recall
Situp	85	7	8	0	0	0	0	100	85%
Forward	3	92	5	0	0	0	0	100	92%
Backward	9	4	87	0	0	0	0	100	87%
LL	1	2	0	74	0	15	8	100	74%
RL	1	1	4	0	82	1	11	100	82%
LFOR	0	0	0	5	1	90	4	100	90%
RFOL	1	1	1	2	3	2	91	100	91%
Total	100	107	105	81	86	108	114		
Precision	85%	86%	83%	91%	95%	83%	80%		

To conclude, the re-sampling based method is important to overcome the main problem which are including offset, crosstalk, rotation effect and scaling. To differentiate the sitting posture, the dynamic time warping based algorithm also has been developed. Some numbers of sitting postures are similar to each other and it makes it harder to differentiate the postures. Further studies will be made to improve the recognition rate.

2.9 Sitting Posture Detection And Recognition Using Force Sensor

In [8], this article shows the usage of pressure sensor to recognize lying and sitting posture. There are two ways to recognize the sitting posture which are by using video camera and pressure sensor. Microcontroller and force sensor were used in this system. To run the experiment, firstly we define the position of Force sensor and amount of force sensor on seat cushions. Secondly, the circuit has been built on microcontroller and the data from the sensor has been obtained. The function of the system in the cushion is to fix incorrect sitting posture for children, elder people and patients.

Five types of sitting posture will be recognized trough the system. Type 1 is proper sitting posture which is the subject is sitting on chair face and backrest as shown in figure 2.20. Type 2 is also for proper sitting posture which is subject sitting on chair face, but no touching backrest as shown in figure 2.21. Type 1 and 2 for improper sitting posture which is crossing legs as shown in figure 2.22 and 2.23. Lastly is crooked sitting posture which is denoted as shown in figure 2.24.

Figure 2.20: Proper sitting posture of type 1

Figure 2.21: Proper sitting posture of type 2

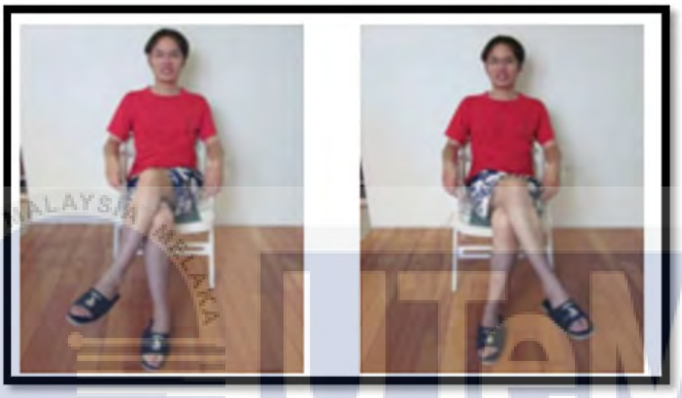


Figure 2.22: Improper sitting posture of crossing legs type 1

Figure 2.23: Improper sitting posture of crossing legs type 2

Figure 2.24: Crooked sitting posture

Force sensors were fix under the chair cushion to detect all the type of sitting posture that has been told, shown briefly in figure 2.25.

Figure 2.25: The cushion and positions of the sensor

When the subject hit the sensor, the reading of flag of the sensor become 1 while if does not hit it the reading will become 0. When the value of flag sensor is {1,1,1,1,1,0,0}, the sitting posture is proper type 1. If the values of flag sensor is {1,1,1,1,0,0,0},the sitting posture is proper type 2. When the value is {1,1,1,0,1,0,0}, it is improper sitting posture of crossing legs type 1(a) and 2(a) while the value is {1,1,0,1,1,0,0}, it is improper sitting posture of crossing legs type 1(b) and 2(b). When value become {1,1,0,1,0,0,1}, it is crooked sitting posture type (a) while {1,1,0,1,0,1,0} is crooked sitting posture type (b).

The simulation system has been done on 7OS and 100b Flexiforce sensor. The microcontroller used is Basic Stamp Ver. 2.5. Figure 2.26-2.33 shows the result of the experiment.

Figure 2.26: Sensors values of Proper sitting posture of type 1

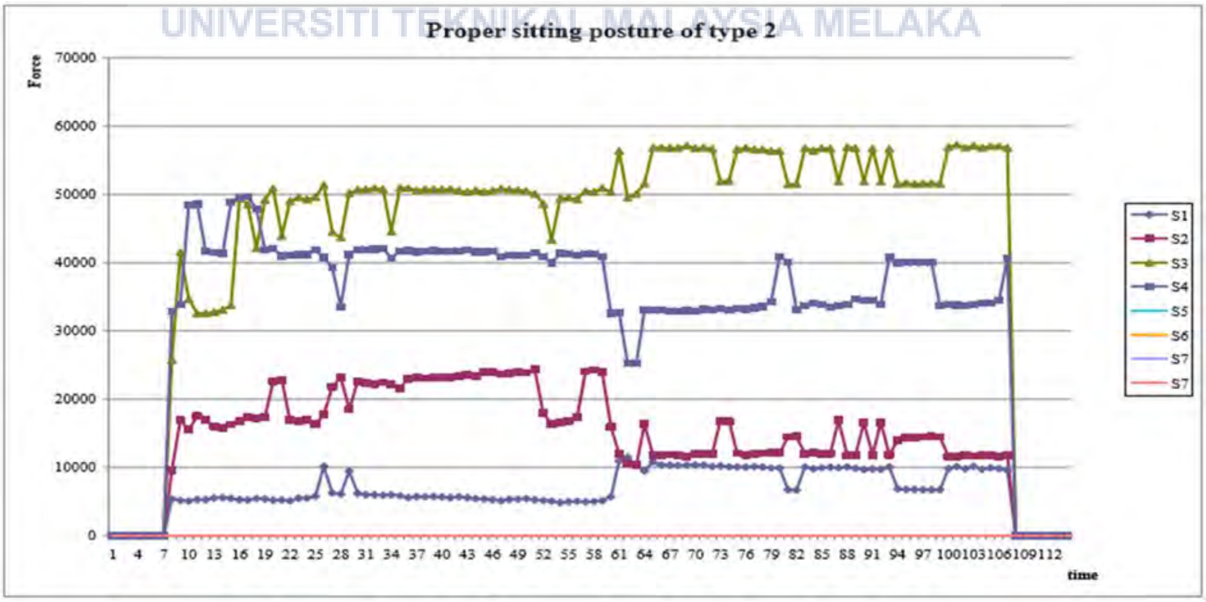


Figure 2.27: Sensors values of proper sitting posture of type 2.

Figure 2.28: Sensors values of crossing legs type 1(a)

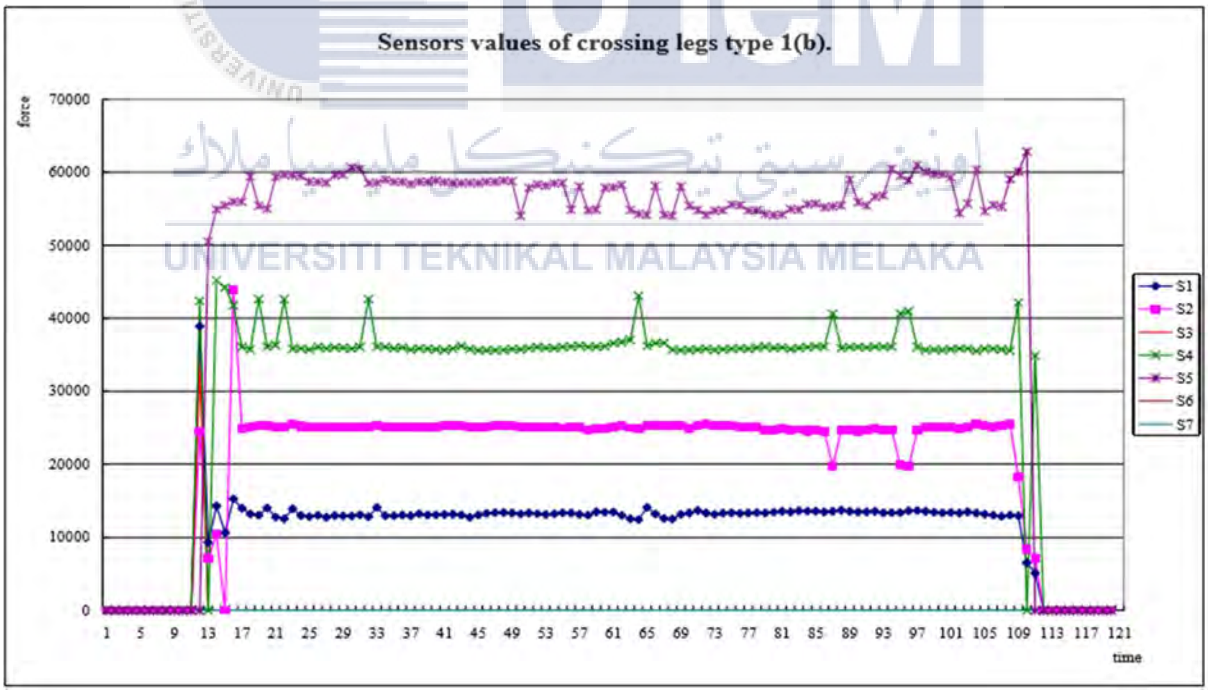


Figure 2.29: Sensors values of crossing legs type 1(b)

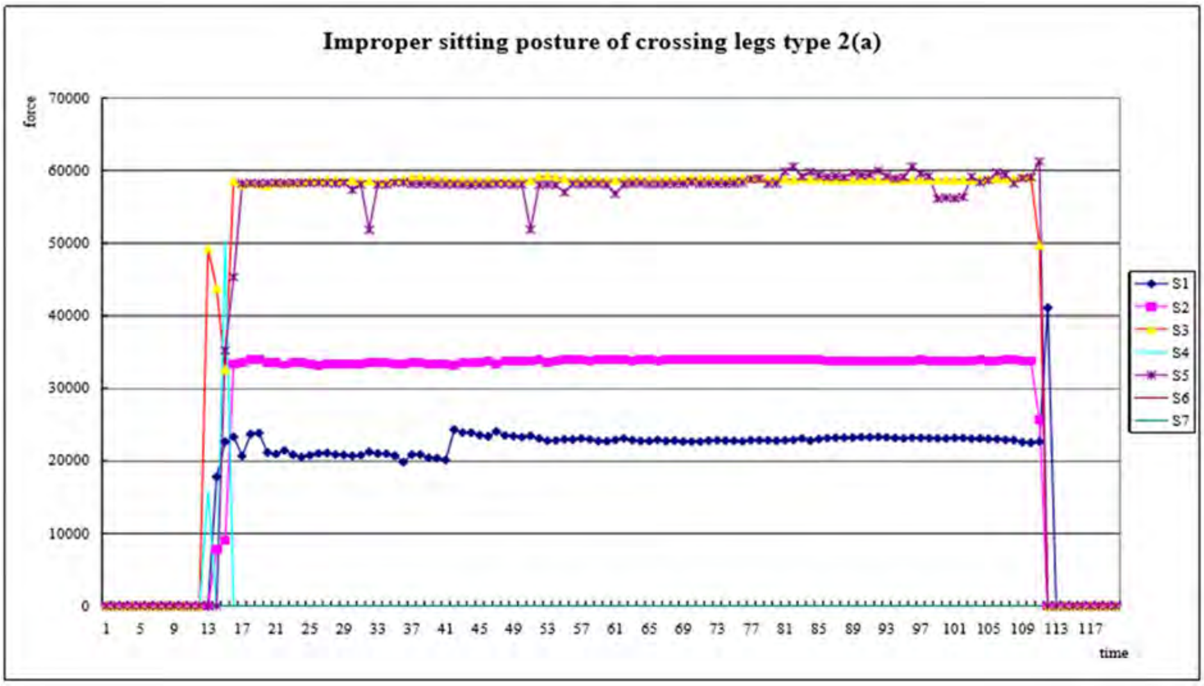


Figure 2.30: Sensors values of crossing legs type 2(a)

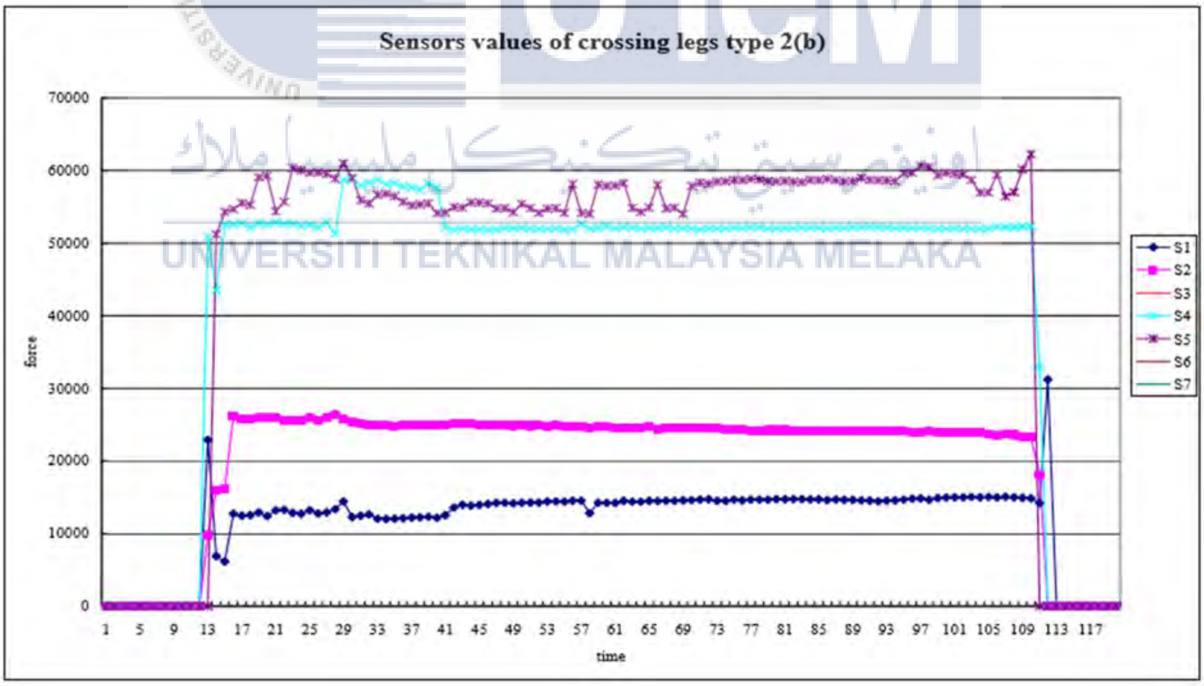


Figure 2.31: Sensors values of crossing legs type 2(b)

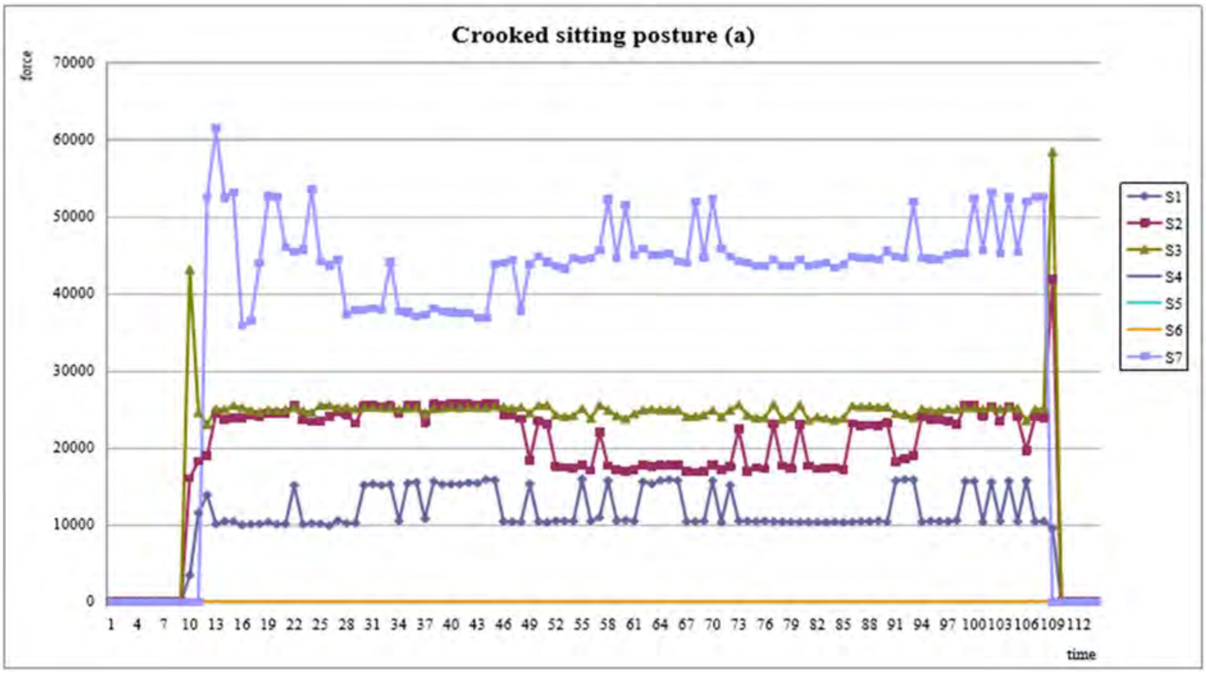


Figure 2.32: Sensors values of crooked sitting posture type (a)

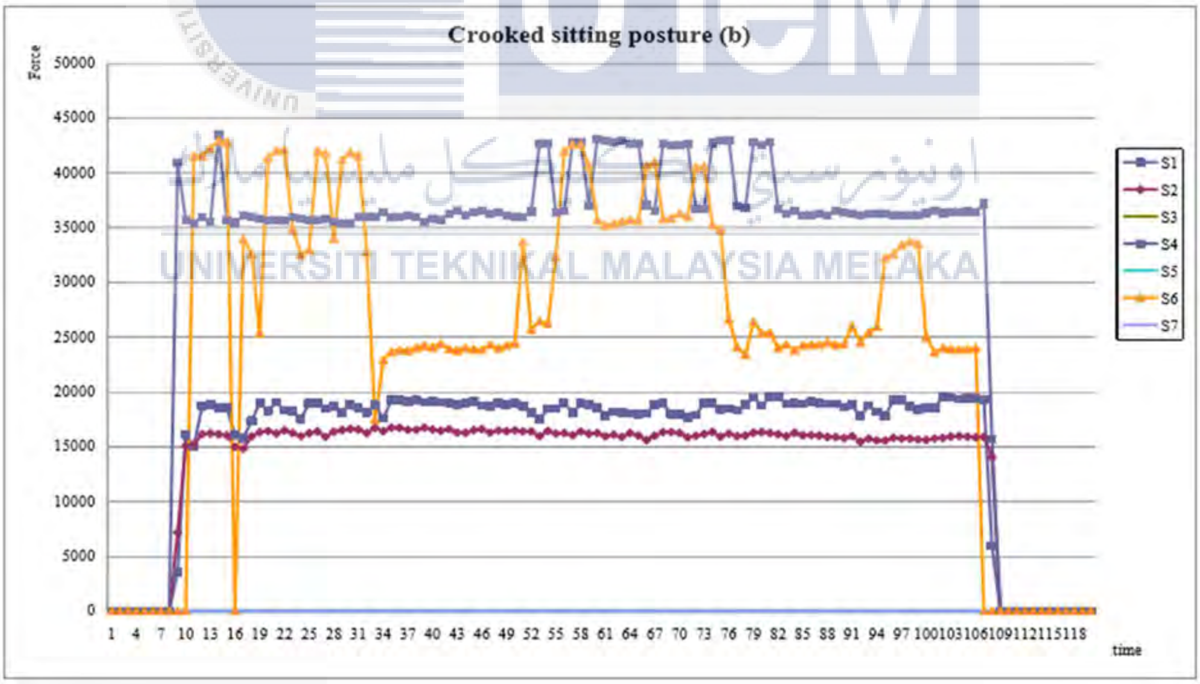


Figure 2.33: Sensors values of crooked sitting posture (b)

2.10 Robust, Low-cost, Non-intrusive Sensing and Recognition of Seated Postures

In [9], the experiment that was investigated is the efficiency of the deployed product by the investigators by using only 19 sensors and commercially-available Tekscan conforMat system which use 2048 sensors. The sensor use in this study is force sensor and the sensor is placed at the same chair use by Tekscan ConforMat system. The same shape of chair were used to get accurate result. Figure 2.34 shows Tekscan ConforMat system chair on the left and our deployed system chair on the right.

Figure 2.34: Left is the Tekscan ConforMat system (2048 sensors) and on the right is our deployed system (19 sensors) installed on the same model of chair

The objective of the experiment is to produce robust generalizability, low cost model by using only 19 sensors to get near optimal placement of the sensor and near real time performance (10Hz) on desktop computer. The study was investigated at five domain places which are office, classroom, automotive, home and assistive technology. Figure 2.35 show the method to develop a low cost, robust and fast learning system for recognizing the classes with high-dimensional data.

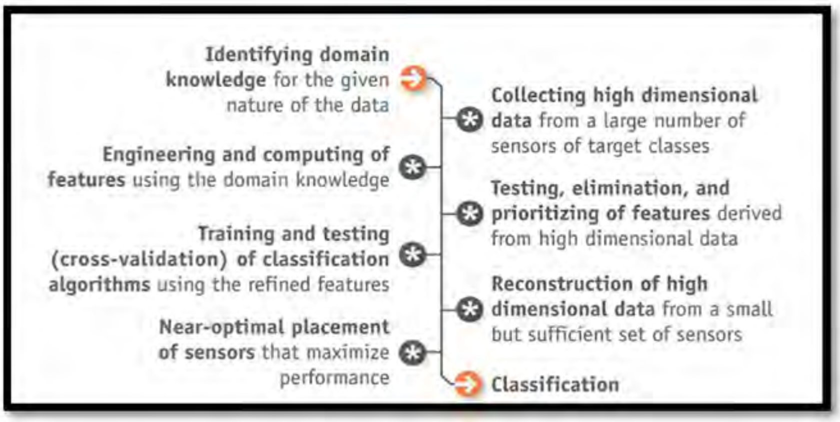


Figure 2.35: Method to develop a low cost, robust and fast learning system for recognizing the classes with high-dimensional data.

The experiment is tested by using 19 and 31 sensors. After the number of sensors has been selected, the near optimal placement of the sensor is described. 10 sitting posture have been investigated and 20 subjects (10 males and ten females, college student) were hired to do the experiment to get the real-world evaluation performance. When the experiment only use 19 sensors, the accuracy of the performance is 82% same with the Tekscan system. When 31 sensors were used, the accuracy became 87%. So, 19 sensors were used to accomplish the objective of the experiment which is low cost as shown in figure 2.36. Figure 2.37 shows the result of the experiment that has been done by using 19, 31 and 4032 sensors.

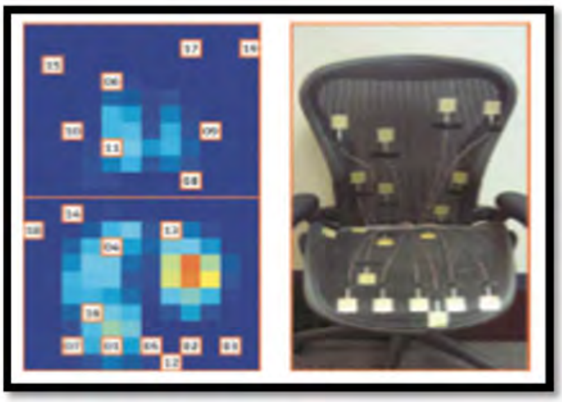


Figure 2.36: The order of the sensor on the chair (19 sensors)

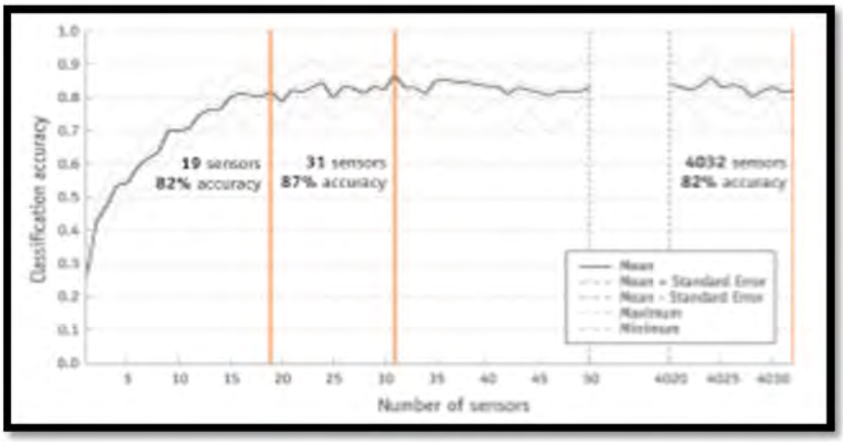


Figure 2.37: Best results were obtained by using 31 sensors (87% accuracy), while by using 19 sensors produce same accuracy (82%) as 4032 sensors do.

2.11 Summary of comparison

Table 2.7: List of criteria from previous studies

Journal / Criteria	Real Time Human Sitting Posture Detection Using Mobile Devices	Feasibility Study of Sitting Posture Monitoring Based on Piezoresistive Conductive Film-Based Flexible Force Sensor	Optimization of Sitting Posture classification Based on User Identification
Position of sensor	Back body (customized girdle)	At chair	4 at chair seat and 4 at backrest
Number of sensor	3	9	8
Type of sensor	Kinect and piezoelectric sensor	Flexible force sensor	Honeywell 24PC series piezoelectric gauge pressure sensor
Frequency	-	100 Hz	8 Hz
Time taken	-	10 s	20s (each posture)
Number of sitting postures	-	3(repeated ten times)	12
Hardware and software	Small and lightweight mobile devices (smartphone and customized girdle)	-	Raspberry Pi or smartphone system
Number of participants	49	7(2 males and 5 females)	2 (1 male and 1 females)
Result	Proper sitting posture (96.67%), improper sitting posture (95.38%)	-	89.0%

Journal / Criteria	Sitting Posture Diagnosis Using a pressure Sensor Mat	Sensitive Cushion Based on Hetero-Core Fiber Optic for unconstraint Sitting Posture Monitoring	eCushion: A Textile Pressure Sensor Array Design and Calibration for Sitting Posture Analysis
Position of sensor	Hipseat and backseat	Hipseat	Hipseat
Number of sensor	16 x 16	4	256
Type of sensor	Pressure sensor	Hetero-Core Fiber Optic Sensor	Pressure sensor
Frequency	2Hz	10 Hz	10 Hz
Time taken for sitting postures	-	60 seconds	-
Number of sitting postures	4	4	7
Hardware and software	-	Multichannel LEDs-PDs, PC and A/D converter	Arduino
Number of participants	2 male	1	25 subjects (15male and 15 female)
Result	-	79%	85.9%

Journal / Criteria	Sitting Posture Detection and recognition using force sensor	Robust, Low Cost, Non-intrusive Sensing and Recognition of Seated Posture	A New Approach for Readout of Resistive Sensor Arrays for Wearable Electronic Applications
Position of sensor	3 at backseat and 4 at hipseat	8 at backseat and 11 at hipseat	Hipseat
Number of sensor	7	19	100
Type of sensor	Force Sensor	Pressure sensor	Resistive pressure sensor
Frequency	-	10 Hz	-
Time taken for sitting postures	-	-	20s
Number of sitting postures	5	10	3
Hardware and software	video camera, windows 7 0S and microcontroller(Basic Stamp version 2.5)	Matlab and Java application	Microcontroller, computer, air pipeline and DAQ unit
Number of participants	1(Male)	20 subjects(10 Males and 10 Females)	1(Male)
Result	-	31sensors (87.0%), 19 sensors (82%)	93.9%

2.12 Summary of advantages and disadvantages

Table 2.8: Advantages and Disadvantages from previous study

Journal	Advantages	Disadvantages
Real Time Human Sitting Posture Detection Using Mobile Devices	• Predict proper and improper sitting posture with high class precision	• Must wear customized girdle everywhere
Feasibility Study of Sitting Posture Monitoring Based on Piezoresistive Conductive Film-Based Flexible Force Sensor	• Clearly discriminate between Backward Leaning and other postures	• Resolution is not high enough • Cannot distinguish between upright and forward leaning posture
Sitting Posture Diagnosis Using a pressure Sensor Mat	• No need to wear the sensor everywhere	• Hard to evaluate the effectiveness of the system • Cannot use for daily basis diagnosis
Sensitive Cushion Based on Hetero-Core Fiber Optic for unconstraint Sitting Posture Monitoring	• Singe mode transmission usage • Flexibility and lightweight	• Only two pattern of seat can be tested (Right, left for pattern 1 and reclining and stooping for pattern 2)
eCushion: A Textile Pressure Sensor Array Design and Calibration	• Overcome problems like offset, crosstalk, scaling and rotation effect	• Situp, backward and forward shared many common

for Sitting Posture Analysis		features that hard to evaluate
Sitting Posture Detection and recognition using force sensor	• Detect sitting situation and incorrect sitting posture for children, patients or elder in future.	• Not produce accurate result.
Robust, Low Cost, Non-intrusive Sensing and Recognition of Seated Posture	• Low cost experiment by using only 19 sensors • Robust generalizability • Near real time performance	• Leaning back and slouching produce confuse result
A New Approach for Readout of Resistive Sensor Arrays for Wearable Electronic Applications	• Low complexity of circuit • Low crosstalk error • Good stability • Low cost • Good reliability • Low power consumption	• Too many sensors use in the experiment

2.13 Comparison method used from previous studies

Based on the journals that have been reviewed, several method had been used to analyse sitting posture. According to [1] and [3], the sensor used to detect the subjects is piezoelectric sensor while [6] use Hetero-core fibre optic sensor and the remaining journal like journal [2], [5], [6], [7], [8] and [9] use force sensor or known as pressure sensor. From three difference sensor that has been used, force sensor shows better performance, good shock resistance and easy to programme compared to the other pressure sensor. The amount of sensors use also is important to get better result. However, the position of the sensors also play important role in giving the expected result despite the minimum amount of sensor used. After make some analysis through all the journals, the sensor place at hipseat and backseat give high accuracy. From [9], the percentage of accuracy for sitting posture is 82% which used 19 sensors only while Tekscan ConforMat system must use 2048 sensor to produce same result.

In order to get better result, average reading must be taken. Based on [6], [7] and [9] it used 10 Hz frequency while [2], [3] and [5] used 100 Hz, 8 Hz and 2 Hz. The frequency is taken based on 1 reading of the sensor in the specific second. It means that if the frequency used is low, the result shows will not satisfied compared to high frequency. For the hardware, [3] used Raspberry Pi while [7] used Arduino to conduct the experiment. Both controller hardware are suitable to run the experiment but Raspberry Pi usually more compatible to the vision module. Arduino is the best hardware to use for sitting posture's study because the experiment does not require camera on it and the programme of Arduino is easy to construct. According to [2] and [4], the data from sensor only valid for 3 type of sitting posture while [3] valid for 12 sitting posture. The experiment will run smoothly if prototype valid for many sitting postures because it gives better performance.

2.14 Conclusion

Based on journals and conference that have been reviewed, there are many ways to investigate sitting posture of the human. Each of the journals and conference shows that there are advantages and disadvantages that can provide useful guidance and knowledge that may lead to good technique. Every year, the technique of investigation has been changed to the most suitable technique. To get accurate result, amount of sensor used and their position at the seat play as an important part of investigation. So, to use minimum amount of sensor in investigation, the position of the sensor must be perfect and to get the best position, the test will be repeat to get average value until the results show is quite same. The selection of sensors that were used also will give different result of the performance. According to most of the journals, force sensor or known as pressure sensor is the best sensor to run the experiment because the efficiency is high and easy to get it with low cost.

From the journal and conference that had been studied, investigation of sitting posture is easy to carry out with the sensor is put at the chair than the customized girdle that stated in previous journal. Customized girdle makes the person feel uncomfortable when wear it and can affect the result of the experiment. So, the effective way to get the result is the sensors must be placed at the hipseat and backseat. This is because the data can be collected through hip and body of the subjects. From previous study, Arduino is the most popular hardware to use because it is understandable and it is easy to get if the hardware is broken. Besides, Arduino is easy to construct and most of the frequency used is 10 Hz. The data of sitting posture will be more efficient with 10 Hz because the frequency is taken based on 1 reading of the sensor at 0.1 second.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter, it will discuss about the objectives and scope which stated in chapter 1. The process, method and development of investigation of sitting posture also will be discuss in this chapter. The methodology will start with 1st objective which is to analyse sitting posture of the students by using Force Sensitive Resistor Sensor(FSR). 2nd objective is to identify the suitable position of the sensor with minimum amount of sensors and the last objective is to identify the relationship between student's sitting posture and focus in classroom environment. The overall flow charts and the procedure to do the experiment are stated in this chapter to explain with detail about all the objective's flowchart. The studies will conduct inside and outside of the classroom for objective 1 and 2. Experiment for objective 3 will conduct in the classroom environment during the class. The experiment will be conduct with difference students for objective 3 and the camera will focus to the student during the experiment. All the data of the sitting posture's performance will be analysed afterward.

3.2 Project Flow Chart

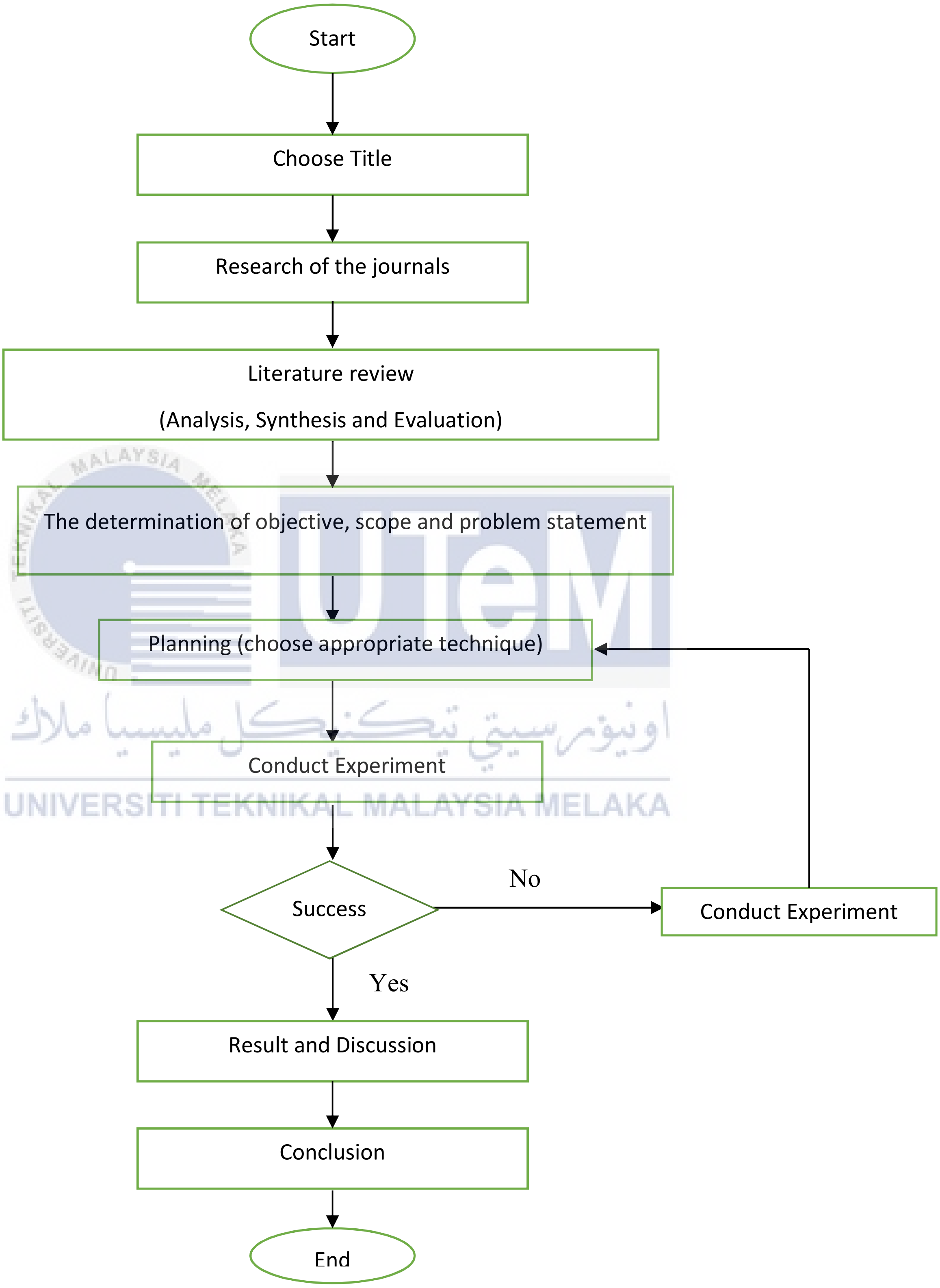


Figure 3.1: Overview of overall project flow

3.3 Component Selection

Investigation of sitting posture is to trace the behaviour of the human while sitting. In order to make a research and fulfil the requirement of the study, the material including electronic component and suitable technique have been chosen. For sitting posture investigation, type of sensor and position of the sensor is the main feature to make the research success. Generally, all technique and material that will be used in this experiment will give some effect to the end result.

Arduino Mega is chosen to perform research and act as a microcontroller to obtain the data from the sensor and interface the output to the computer. This microcontroller also act as a brain to the process. All the input and output must through the microcontroller to get and processing the data. Before the experiment begin, there must be an instruction (coding) to control the whole process including frequency, threshold value and delay timer. The data from the experiment will send to the computer to make a conclusion. Besides, Arduino mega also is chosen because it read data with high speed and to make the investigation run smoothly, it needs this feature of high processing speed.

The selection of sensor is one of the important parts to give better result. Based on the cost and its functionality, Force Sensing Resistor (FSR) sensor is chosen. This type of sensor is inexpensive and easy to get and if there is problem with one of those sensors, it can be replaced anytime due to most of the electronic shop sell the sensor. The sensors are easily to program and it able to read the instruction perfectly.

3.3.1 Arduino Mega

The Arduino Mega is a microcontroller and act as a main brain of the investigation process. It is a board based of the ATmega2560. Overall, it has exactly 54 digital input and output pins which 14 of it can be used for PWM output, 4 UARTs which is hardware serial ports, 16 analog inputs, 16 MHz frequency crystal oscillator, power jack, reset button, an ICSP header and important part of the microcontroller which is a USB connection. To start the arduino, battery or AC-to DC- adapter can be used or the other ways to start it with a USB cable connect to the computer. The speciality of using Arduino Mega is, it is compatible with the designed for Arduino Diecimila or Duemilanove.

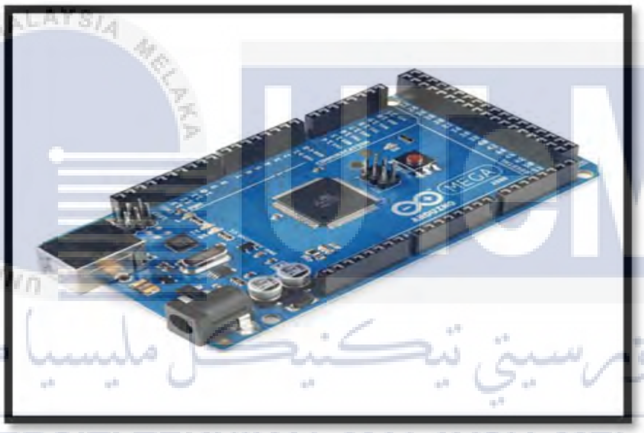


Figure 3.2: Arduino Mega [10]

Table 3.1: Specification feature of Arduino Mega

Operating Voltage	5V
General digital Input/Output Pin	54 (14 PWM outputs)
Analog Input	16
Clock speed	16Mhz
Memory	256k Flash Memory
Input voltage	7-12V
EEPROM	4 KB
SRAM	8 KB

3.3.2 Force sensitive resistor sensor Module

Force sensitive resistor (FSR) also known as force sensing resistor. It is a special type of resistor due to its capability of varying the value of the resistance when there is varied force or pressure that applied into it. The FSR technology are made up from conductive polymer which are sensitive when there is a pressure or force applied on it. The sensing film of FSR sensor will activate the particle to touch the conducting electrode if there is a force applied and it will change the resistance of the film. FSR is chosen instead the other based sensor because it can operate in difficult environments and easy to control. The other advantages using this sensor are it has thin size which is less than 0.5mm, good shock resistance and low cost. Force sensing resistors also called as polymer thick film devices (PTF).

Figure 3.3: Force Sensing Resistor sensor Module [11]

Table 3.2: Specification feature of Force sensing resistor sensor

Sensing Area (diameter)	12.7 mm
Minimum Pressure	100 g (0.22 lb)
Maximum pressure	10, 018 g (22.04 lb)

3.4 Overview of process and hardware

Table 3.3: Overview of the process and hardware

Movement	Human : • Write instruction (coding) to main controller. • Receive data from Arduino Mega.
Controller	Arduino Mega: • Main controller of the process • Give instruction to the sensor • Receive data from the sensor
Sensor	Force sensor: • Connected with Arduino Mega • Detect weight of an object

The process is begin when instruction is delivered to the controller by human. The controller (Arduino Mega) is act as a brain of the experiment. Next, the controller will give instruction to the force sensor. Force sensor will detect force based on the frequency and coding that has been stated in the programme. Data from the sensor will transfer to the microcontroller and the result will appear at the Arduino software.

3.5 Objectives Summary

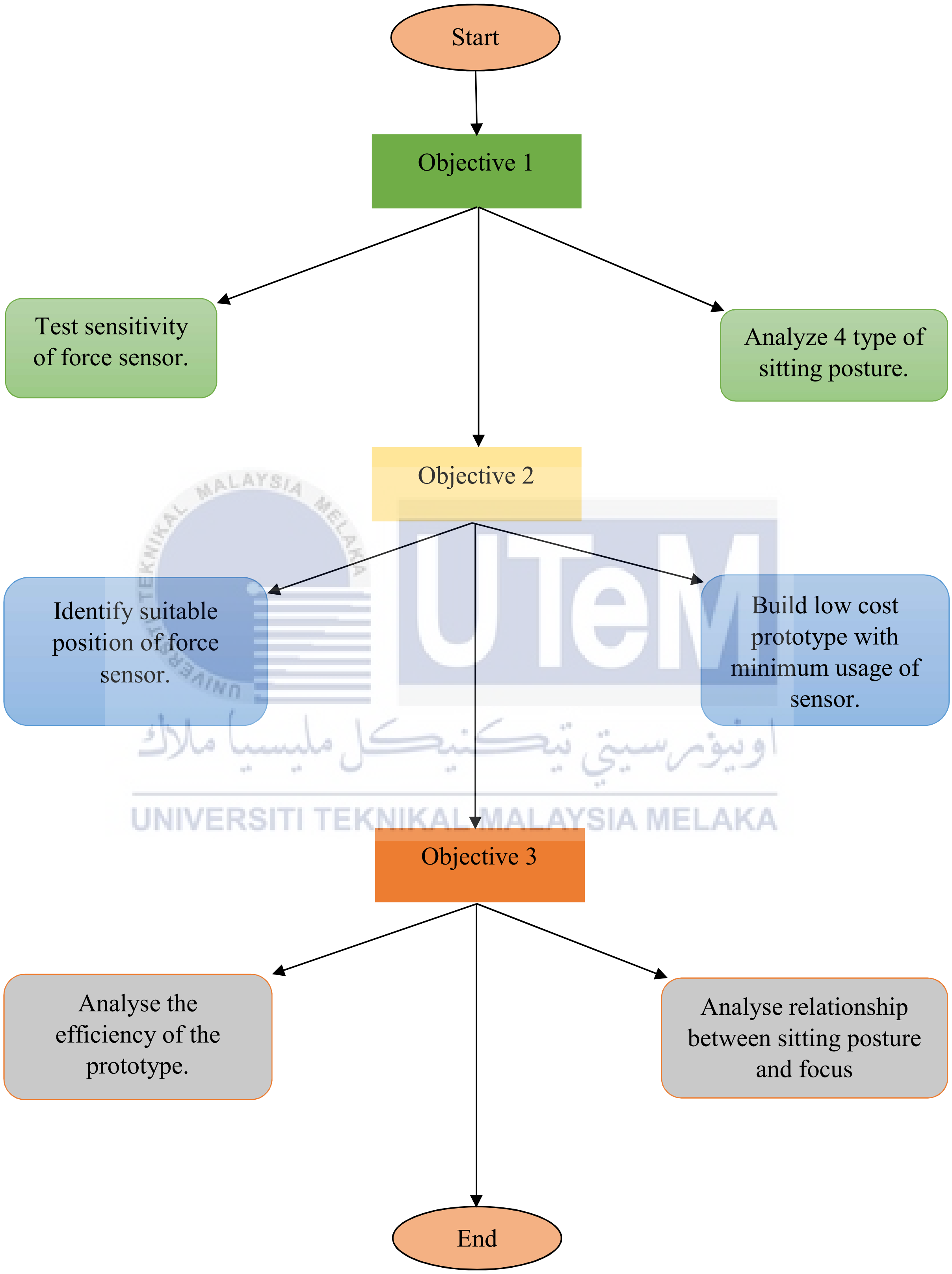


Figure 3.4: Objectives Summary

3.6 Algorithm of Sitting Posture (Objective 1)

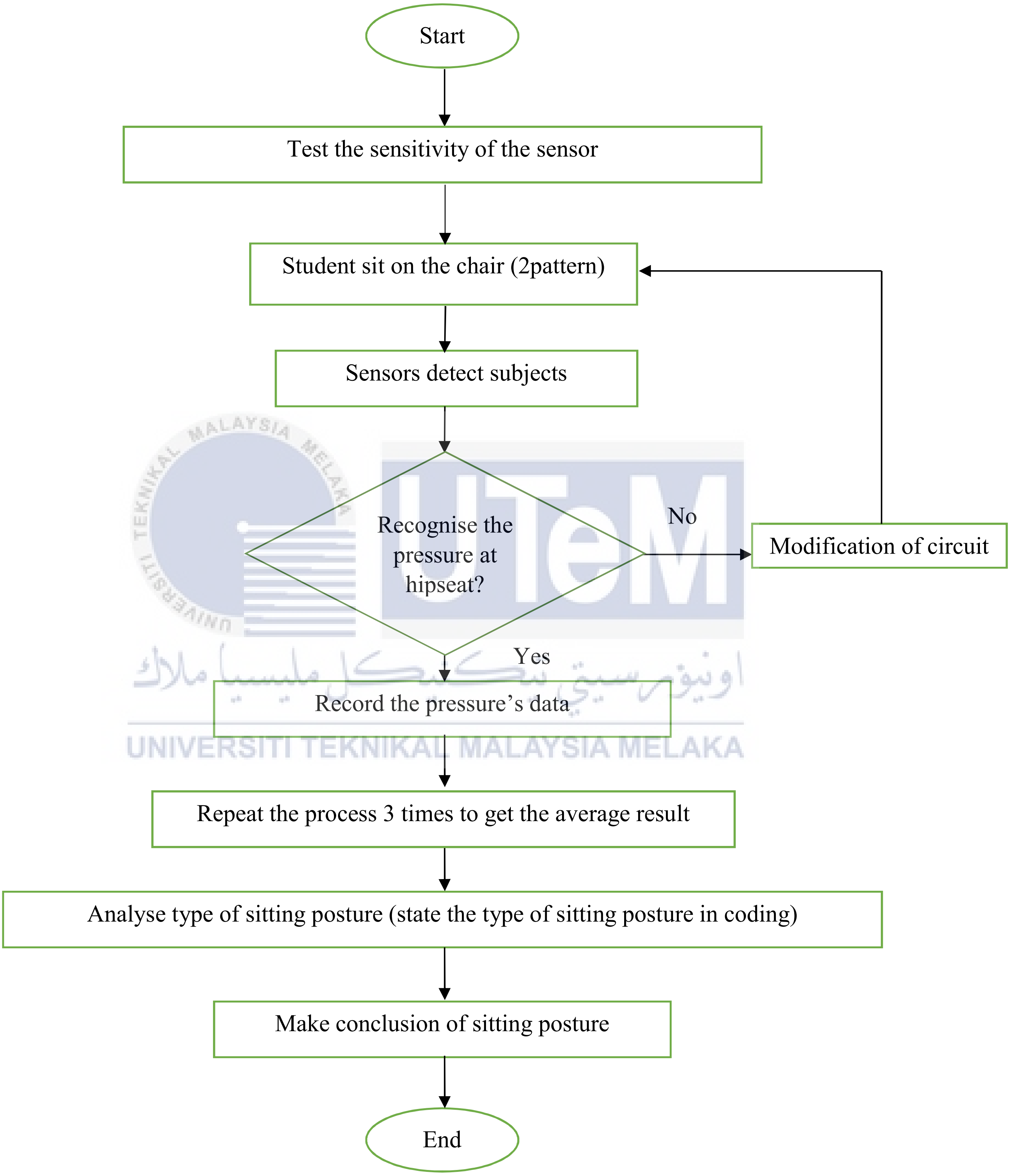


Figure 3.5: Flow chart of Sitting Posture Algorithm

3.6.1 Experiment setup

In this section, there are two experiments will be conducted. The first experiment is to test the sensitivity of the sensor and the second experiment is to analyse four type of sitting posture by using only 4 sensors. The sensitivity of the sensor will be test by hit some force on it and observe the changes of the result at serial monitor. The second experiment, there will be 3 subjects with different weights. A student with 65 Kg, 51 Kg and 42 Kg with 171 cm, 163cm and 158 cm height are chosen to be part on this experiment. The experiment is set up with 1 Hz frequency to get 4 types of sitting posture. Each of the sitting posture must be recorded for 10 seconds and repeat the experiment 3 times to get average value. To make sure the sensors are in good condition, take the analog reading for the first and last 5 seconds at the serial monitor and make sure the reading shows 0 step which is 0 Volt. The graph for each type of sitting postures also will be shown by getting the average value based on summation of all the repeated experiments according to their seconds.

3.6.1.1 Sensitivity of the sensor

Experiment outcome

The researcher of this experiment is able to:

1) Analyse the sensitivity of the sensor.

To test the sensitivity of the sensor, apply the force to the Force Sensitive Resistor (FSR). If the reading that come out at the serial monitor increase, it means the FSR is directly proportional with the analog value. The sensor was set with the range of light touch, light squeeze, medium squeeze and big squeeze. When the reading shows 0 analog value, it means there is no pressure act on it. The serial monitor will display light touch when the reading is from 1 to 150, light squeeze when 151 to 350, medium squeeze from 351 to 500 and lastly big squeeze when the reading 501 and above. The Equation (1) is describe as following to prove the FSR is directly proportional with the analog value.

$$\frac{FSR}{FSR+10K\Omega} \times 5v = Analog\ Value \qquad (1)$$

Where;

FSR – Force Sensitive Resistor

$10K\Omega$ - Resistor

$5v$ – Power Supply

$Analog\ Value$ – Analog Reading (Step)

Experiment instruction

For starting, the sensor must be test with zero force on it. Make sure there is no object hit on it. Take the reading of the sensors at the beginning of the experiment. Set the threshold value to make the researcher easy to define the force that acting on it like little touch, little squeeze, medium squeeze and big squeeze.

Experiment procedure

1) Set the experiment by connecting a sensor to Arduino.
2) Take the reading of the sensor with zero force on it.
3) Apply some force at the sensor by put weight on it.
4) Take the analog reading of the sensor.
5) Repeat step 3 by increase the force.
6) State if the reading of the force is increase while the weight that hit on it is increase.
7) Make conclusion.

Experimental data

The result of the experiment will be tabulate in a graph and table form. The data will be analyse to make further analysis.

3.6.2 Sitting posture experiment

Two pattern of sitting of sitting posture are proposed in this study. Pattern 1which is back and front sitting posture while pattern 2 which is left and right sitting posture.

3.6.2.1 Pattern 1

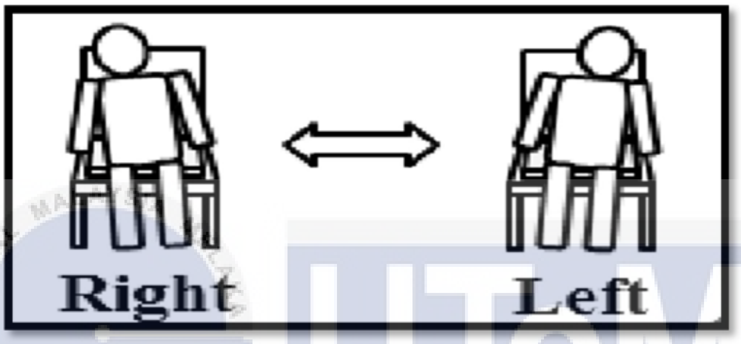


Figure 3.6: Pattern 1 (Right and Left position) [3]

3.6.2.2 Pattern 2

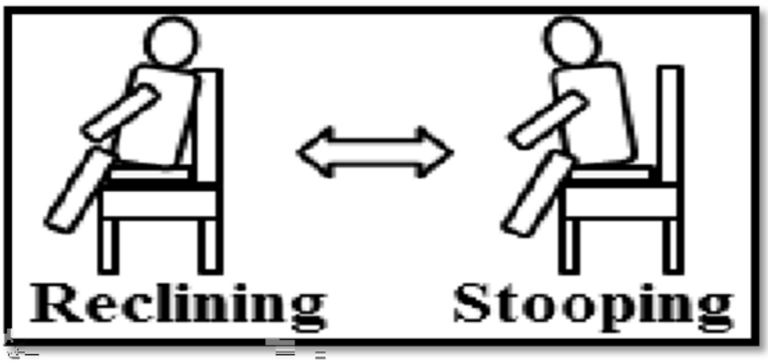


Figure 3.7: Pattern 2 (reclining and stooping position) [6]

Experiment outcome

The researcher of this experiment is able to

1) Analyse the sitting posture of the students by using 4 sensors.
2) Know how to set the threshold value before conducting second experiment.

Experiment instruction

Before starting this experiment, make sure the sensors can function well. Next, place the position of the sensors as shown in figure 3.8.

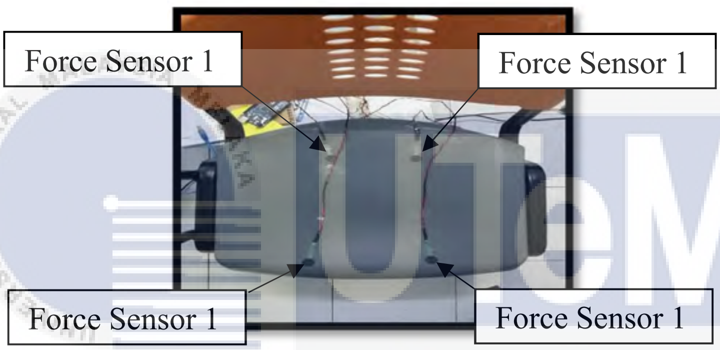


Figure 3.8: Position of the sensor at the chair

Front left;1, Front right;2, Behind left;3, Behind right;4

Experiment procedure

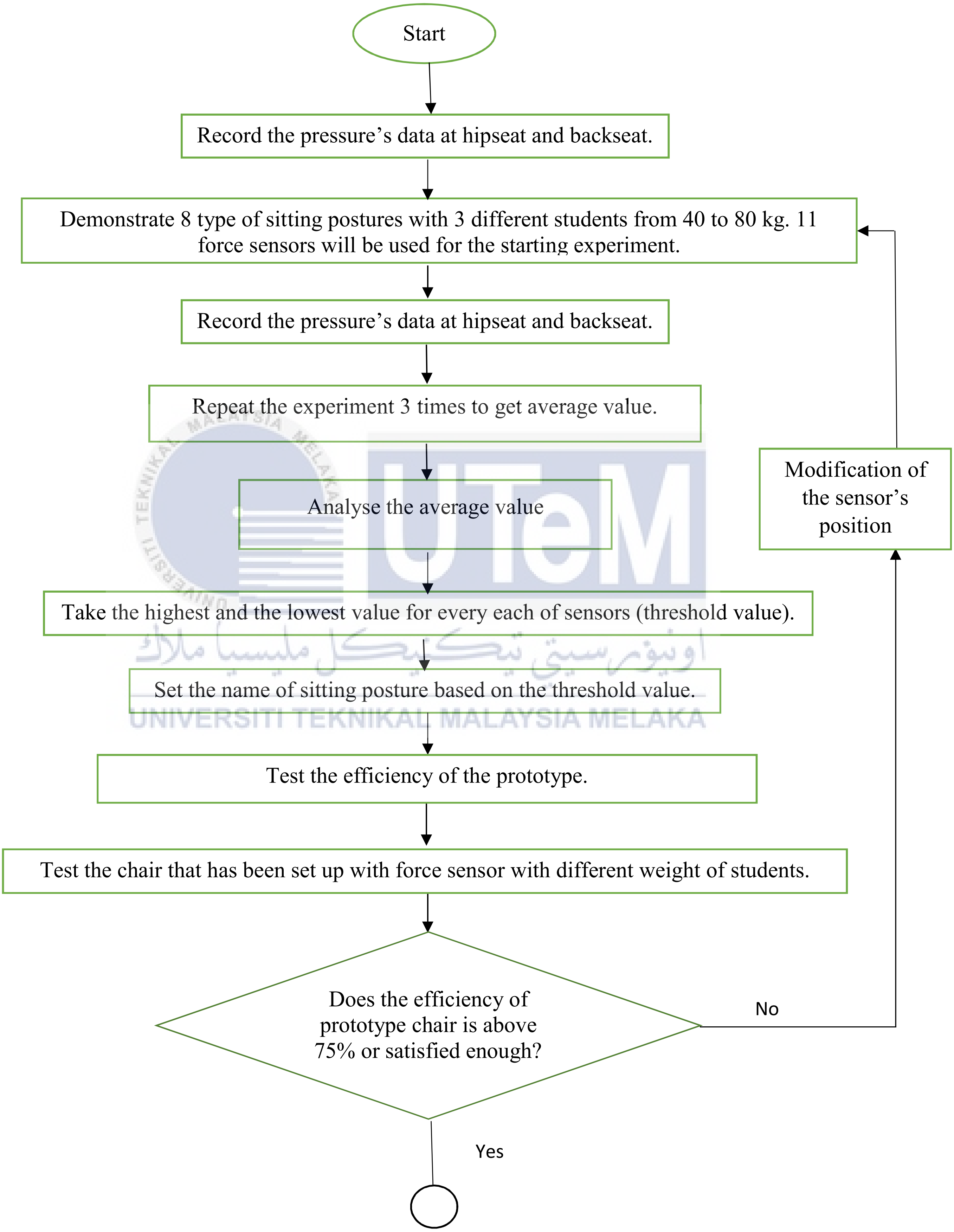
1) Set up the experiment as shown in figure 3.8.
2) Take the data at the beginning of the experiment with zero force on it.
3) Perform sitting posture of pattern 1 as shown in figure 3.6.
4) Take the data of the sitting posture and make conclusion.
5) Perform sitting posture of pattern 2 as shown in figure 3.7.
6) Take the data of the sitting posture and make conclusion.
7) Repeat step 3 to 4 and step 5 to 6 for 3 times. Get the average value and tabulate the table and graph.
8) Repeat step 7 with the other 2 students with different mass.

9) Analyze the data from all the experiment and set the threshold value for the sensor that does not show clear result (cannot be compared).

Experimental data

The result of the experiment are tabulated in a graph and table form. The result's data will be analyzed for further analysis.

3.7 Project Flow Chart (Objective 2)



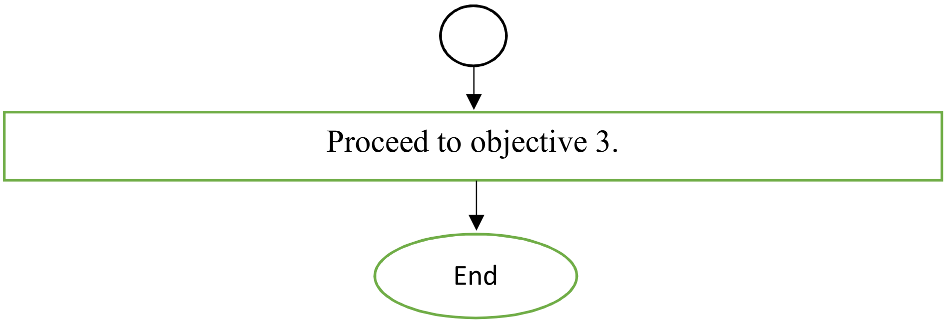


Figure 3.9: Flow Chart of position sensor

3.7.1 Hardware

There are 2 design are proposed in this project.

1. The sensor at the hipseat (Design 1).
2. The sensor at the hipseat and backseat (Design 2).

3.7.1.1 Design 1

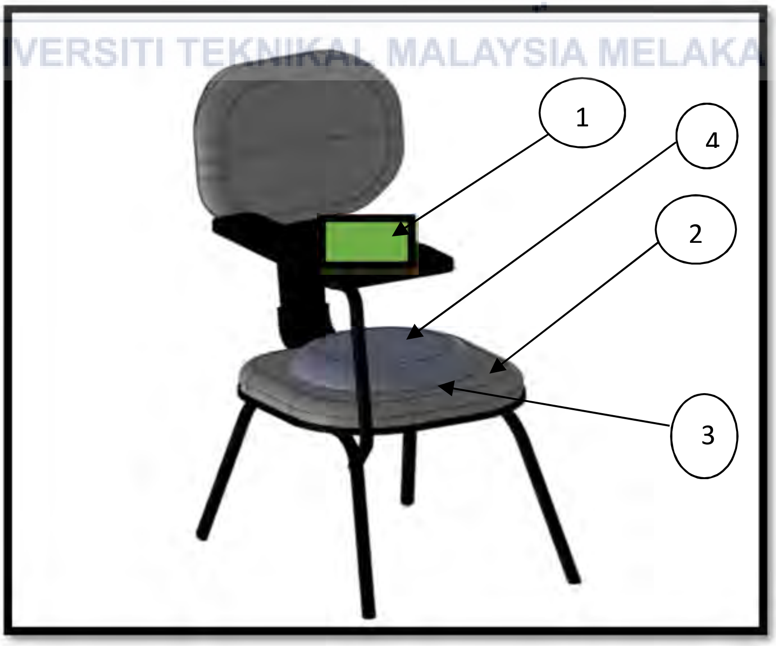


Figure 3.10: Design 1

Table 3.4: Component of prototype design 1

1	Arduino Mega
2	Seat
3	Cushion
4	Force sensor (hipseat)

3.7.1.2 Design 2

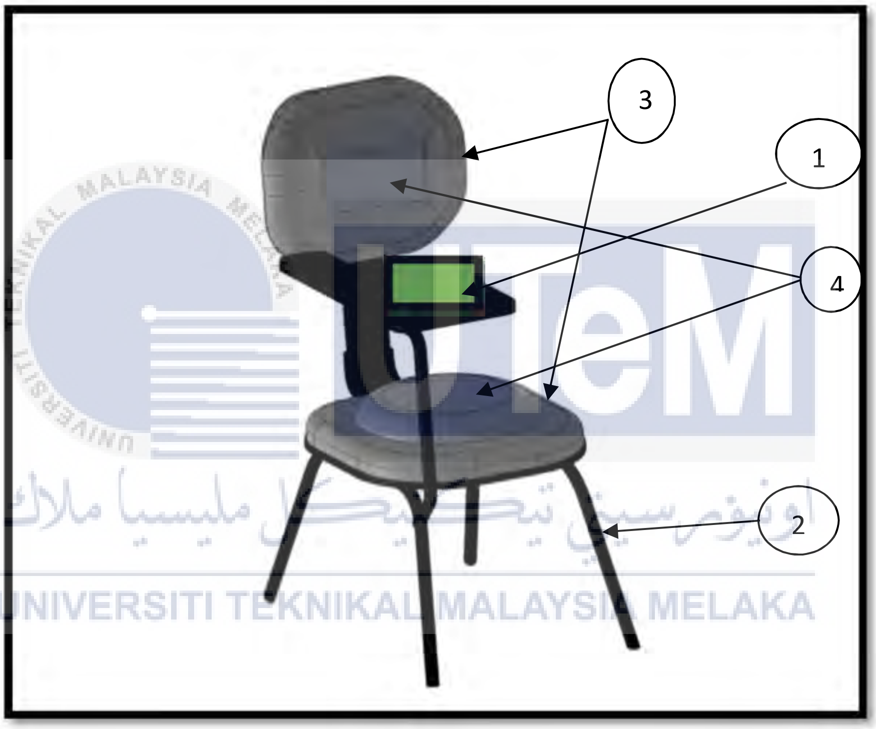


Figure 3.11: Design 2

Table 3.5: Component of prototype design 2

1	Arduino Mega
2	Seat
3	Cushion
4	Force sensor (hipseat and backseat)

From both of the design, there is little difference about the placement of the sensor. Design 1 and 2 are equipped with Arduino mega to control the process. Arduino is use in this study because it is easy to construct and it is lighter hardware. From the investigation that has been done, the circuit for both design are almost same and design 2 will give more accurate reading value. The chair that will use for both experiments are classroom's chair. The force sensor will be implements in the cushion at the hipseat for design 1 and hipseat and backseat for design 2. So, design 2 need more cost to construct the circuit than design 1 due to the placement of the sensor at the seat. In term of result, more data of sitting posture can be collect from design 2 and to manipulate the data is very easy compare to design 1 and it will give best result. So, designed 2 was chosen to conduct for the next experiment.

3.7.2 Experiment setup

In this section, the experiment will be conducted outside or inside of the classroom environment. The experiment starts with 11 sensors mount on a chair. 8 type of sitting posture that the students did during the experiment will be test in class which are leaning forward, leaning back, seated upright, leaning right, leaning left, right leg crossed, left leg crossed and slouching on a chair. If the prototype can read all type of sitting posture but the efficiency is below 75%, the sensor must be added. If the result of the efficiency is above 75% but still do not satisfied with the result, the position of the sensor must be change until the result is satisfied enough.

3.7.2.1 Prototype validation test

Experiment instruction

At the beginning, place 11 sensors at a classroom's chair and put it in a suitable position. Make sure all the sensors are in coverage area of the seat. Next, test the Force sensors without students sit on it. If any of the sensor show analog reading value, stop the experiment and change the error Force Sensor or check the connection of the sensor. This is to make sure the experiment give the accurate value.

Experiment procedure

1) Set the experiment with 1 Hz frequency.
2) Set up 11 sensors on a chair. The position of the Force sensors are place at the hipseat and backseat where the average of human's muscle hit the focus point at chair when seat.
3) Take the Analog reading for 5 seconds before the student sit on the chair to ensure the sensors are in good condition and the result show at the serial monitor is "none".
4) After 5 seconds, the student will be instructed to seat in the posture of leaning back, seated upright, leaning forward, leaning right, leaning left, right leg crossed, left leg crossed and slouching for 20 seconds.
5) Take the analog reading at serial monitor for all type of sitting posture that will do by the students.
6) Repeat the experiment 3 times to get average value.
7) Analyse the average value.
8) Take the highest and the lowest value for every each of sensors (threshold value).
9) Set the name of sitting posture based on the threshold value.
10) Test the efficiency of the prototype.
11) Test the prototype with different students.
12) If the result is not satisfied, change the position of the sensor and repeat step 2 to 11. If the result still not satisfied, repeat step 2 to 10 by add the more sensor. If the result is satisfied enough, proceed to step 13.
13) Record the result and proceed to objective 3.

Experimental data

The result of the experiment are tabulated in a graph and table form. The data will be analyze to make further analysis of sitting posture.

3.8 Sitting Posture and Focus Flow Chart (Objective 3)

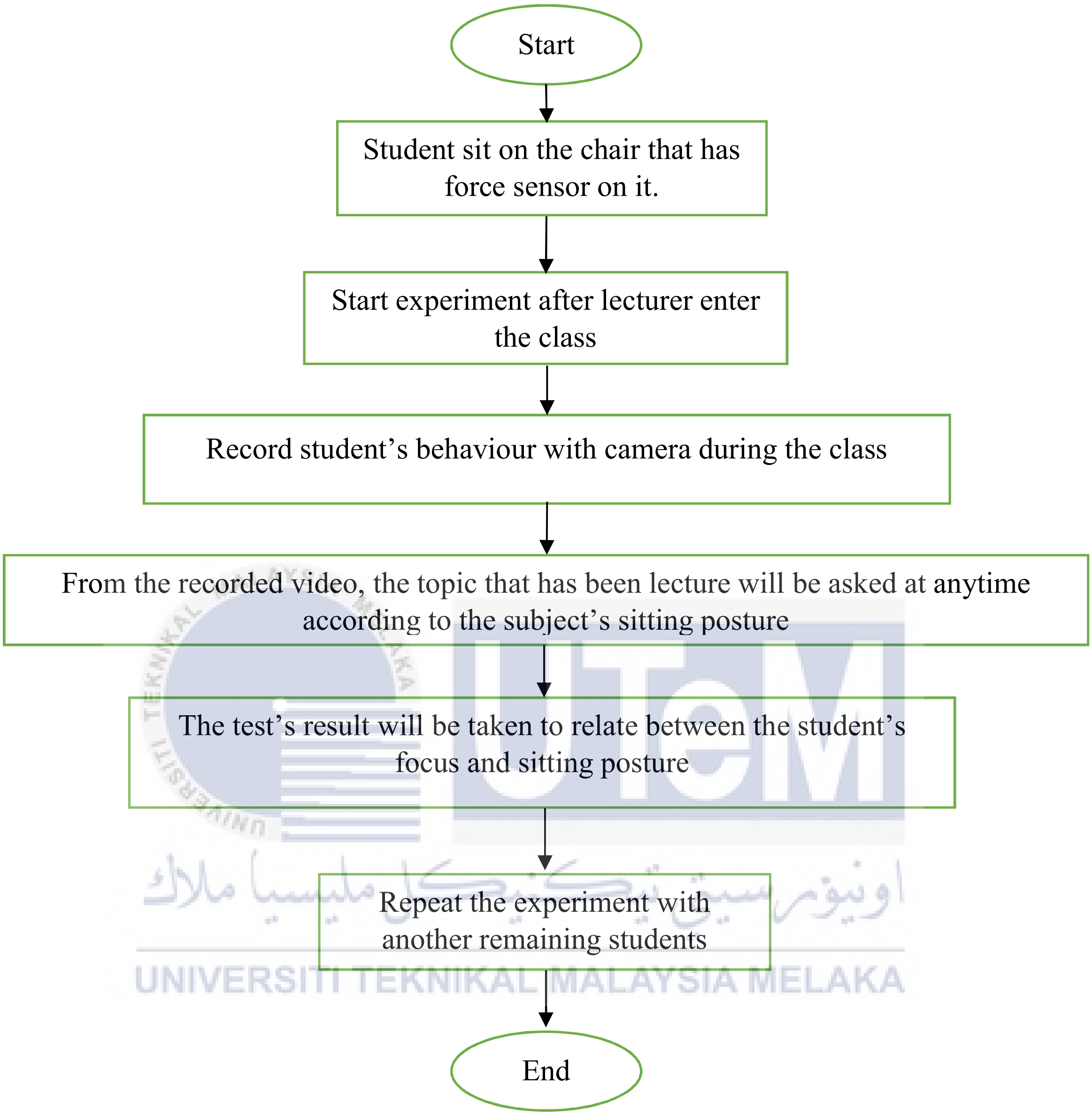


Figure 3.12: Flow Chart of investigation of the relationship between sitting posture and focus of the students

3.8.1 Experiment setup

In this section, the experiment will be held at the classroom environment. The prototype from objective 2 is use in this section to get the data of sitting posture that will done by the students. 11 students will be chose to do this part of experiment. There will be a test with multiple choice question for the participated students to analyse their focus during the class. The data of sitting posture also will be taken to relate it with the focus.

3.8.1.1 Sitting posture and focus investigation

Experiment outcome

The researcher of this experiment is able to:

1) Perform low cost prototype with minimum amount of sensors to investigate student's sitting posture and focus.
2) Identify which type of sitting posture will affect the student's focus.

Experiment instruction

The prototype that was built in objective 2 is use in this experiment to study about the relation between student's sitting posture and focus. Camera will record all the movement done by the students along the lecture class but the result that will be taken based on the question that will be asked. The test will be in multiple choice question only because it is to analyse the focus not the clever of the student. Experiment will be proceed when the lecture start.

Experiment procedure

1) Set the experiment by using prototype from objective 2.
2) Tell the subject to seat on the prototype that was built.
3) Record the student's behaviour during the class.
4) From the recorded video, the topic that has been lecture will be ask anytime according to the subject's sitting posture.
5) Take the test's result of the test (multiple choice question).
6) Make conclusion about the student's sitting posture with their focus based on the result of the test.

Experimental data

The result of the experiment are tabulated in a graph and table form. The data will be identified and make the final conclusion about the student's focus and their sitting posture.

CHAPTER 4

RESULT AND DISCUSION

4.1 Introduction

In this chapter, 4 force sensitive resistor had been tested in objective 1 to investigate 4 type of sitting posture which are back, front, left and right sitting posture. While in objective 2, 11 sensors have been mount on a chair and 8 type of sitting posture can be read by all the sensors. The prototype that has been built in objective 2 will be use in objective 3 to get the result of the subjects. In this chapter, all the experiment setup for objective 1 until objective 3 will be shown and the result will be discussed. The prototype only test to the person with 40 to 80 kilogram.

4.2 Experimental Data (Objective 1)

Two experiments were conducted in first objective. First experiment is to test the sensitivity of the force sensor and the second experiment is to analyse 4 type of sitting posture by using only 4 Force Sensor.

4.2.1 Experimental Result for the sensitivity of the Force Sensor

Figure 4.1 shows how the connection of the Force Sensitive Resistor (FSR) with the Arduino board. 10 KΩ resistor was used in this experiment by connecting it with 5V pin Arduino board.

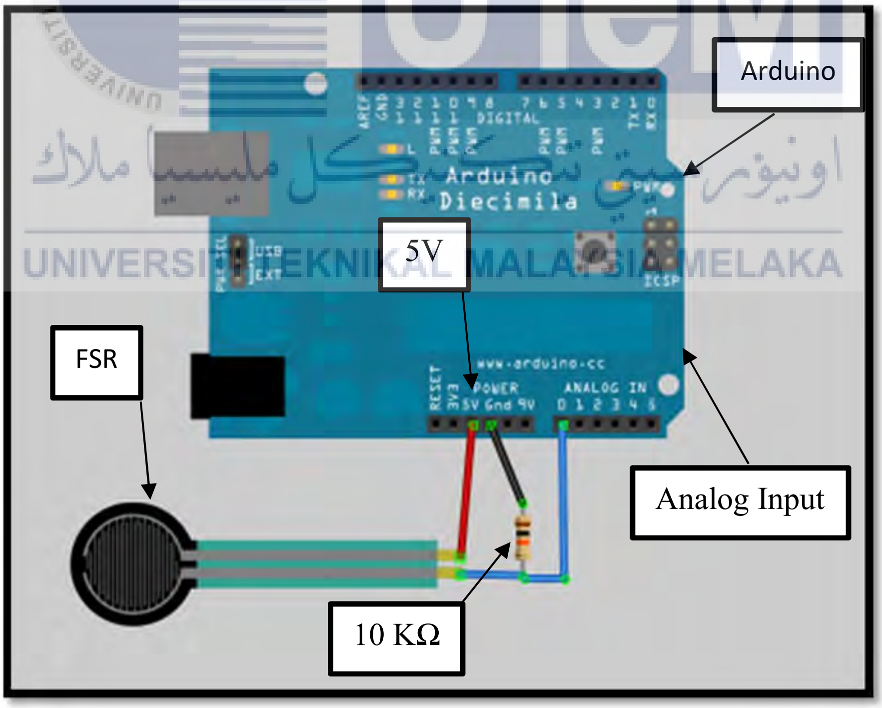


Figure 4.1: Connection of the sensor

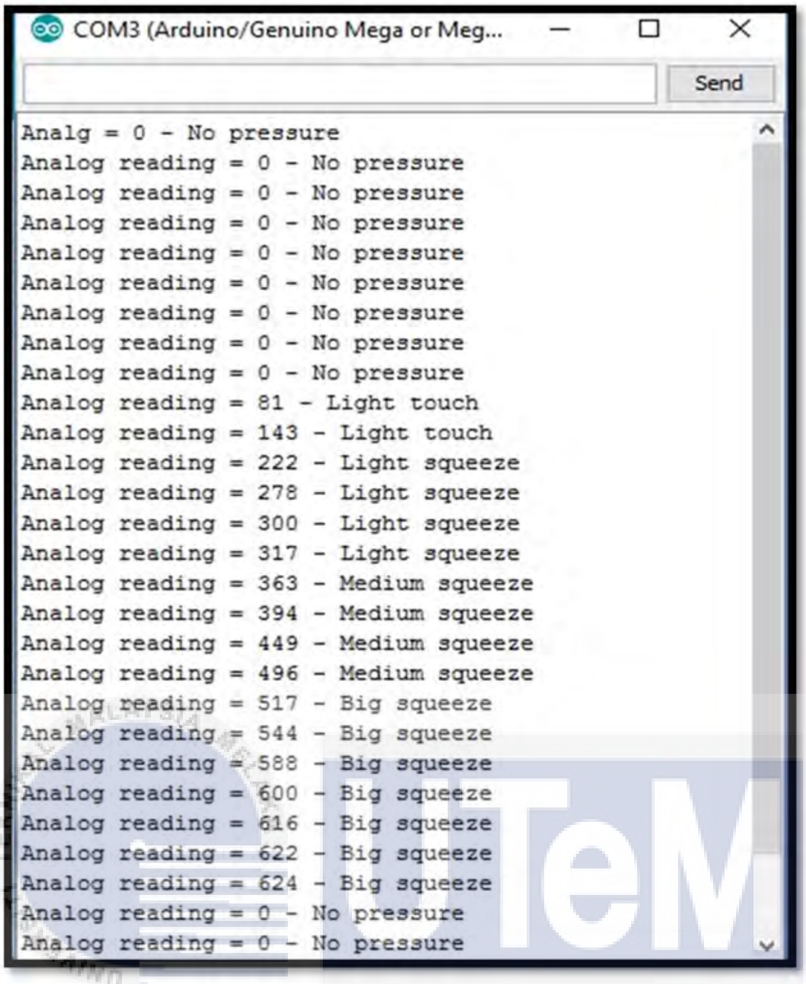


Figure 4.2: Serial monitor

Figure 4.2 shows the result of the sensitivity of the Force Sensor when there is different forces hit on the Force Sensor. The sensor was set with the range of light touch, light squeeze, medium squeeze and big squeeze. When the reading shows 0 analog value, it means there is no pressure act on it. The serial monitor will display light touch when the reading is from 1 to 150, light squeeze when 151 to 350, medium squeeze from 351 to 500 and lastly big squeeze when the reading 501 and above.

4.2.1.1 Discussion based on the sensitivity of the Force Sensor

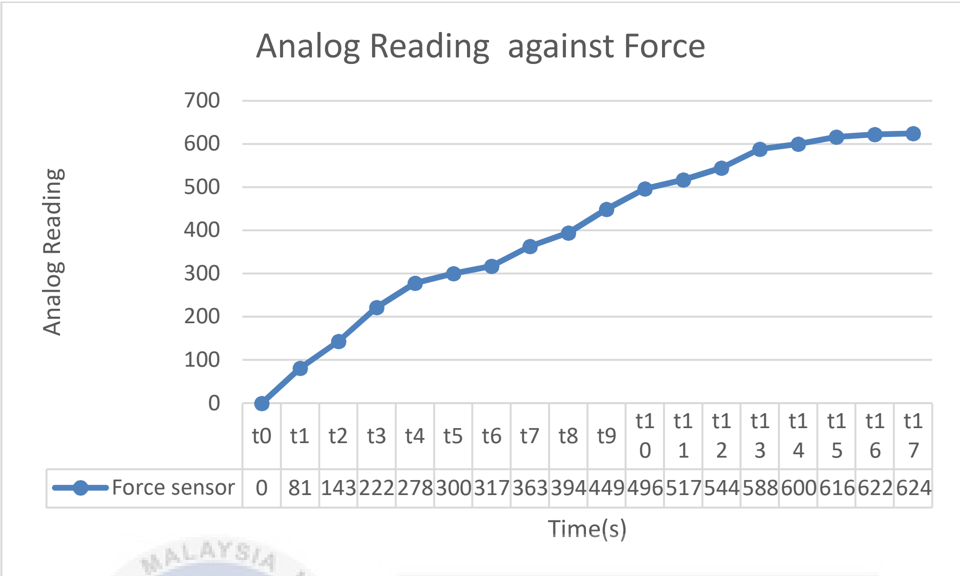


Figure 4.3: Graph of the sensitivity of the Force Sensitive Resistor (FSR)

Figure 4.3 shows the changes of the analog value in graph form. By using Equation (1) it shows the reading is increase when the force is applied on it and it proved the Force sensitivity Resistor is directly proportional to the analog reading value. The higher the force applied to the sensor, the higher the reading value. When there is no force applied to the FSR, the serial monitor show no pressure and when the force that exerted on it increase by the time (Second), the serial monitor show light touch, light squeeze, medium squeeze and lastly big squeeze which means there is big force on it. The Reading of the Force Sensor also will be changed when there is cushion put on the Force Sensor. The force must be higher than usual as to get the same reading as no cushion. So the sensitivity of the sensor also will be difference depends on the thickness of the cushion or type of the cushion.

4.2.2 Experimental Result for Four Type of Sitting Posture

Figure 4.4 shows the prototype of objective 1 with their measurement detail as shown in Table 4.1. Figure 4.5 shows four type of sitting posture which are back sitting posture, front sitting posture, right sitting posture and left sitting posture that has been performed by one of the subjects and have been analysed by using only 4 Force Sensitive Resistor (FSR) that had been placed on the chair.

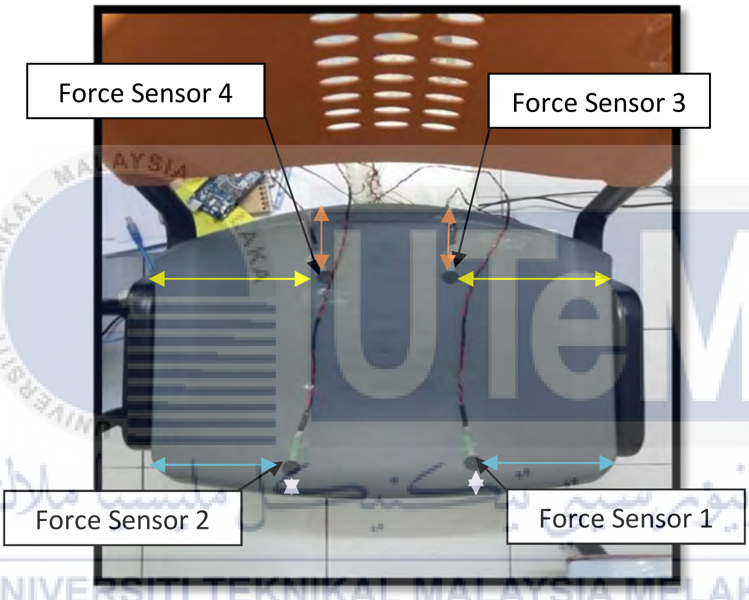


Figure 4.4: Prototype of objective 1

Table 4.1: Measurement detail for prototype objective 1

Colour	Distance (Cm)
	14.2
	5
	9
	12.5

(a) (b) (c) (d)

Figure 4.5 (a): Back sitting posture. (b): Right sitting posture. (c): Left sitting posture. (d) Front sitting posture.

The result of the experiment are tabulated in a graph and table form. Below shows how the data of the student which is 65Kg mass and 171 cm height is collected. The data of the other subjects will be summarize shortly and the overall data will be analysed to make further analysis of sitting posture.

Table 4.2: Back sitting posture

	Experiment 1				Experiment 2				Experiment 3			
	FSR1	FSR2	FSR3	FSR4	FSR1	FSR2	FSR3	FSR4	FSR1	FSR2	FSR3	FSR4
ANALOG READING	286	347	822	787	350	346	804	777	182	236	811	815
	283	341	823	789	357	350	808	782	138	220	818	825
	281	337	824	790	361	349	807	783	138	221	814	810
	285	336	823	793	360	349	807	785	115	241	814	818
	291	345	825	793	365	353	807	787	153	251	812	815
	293	343	824	795	362	321	806	788	153	249	811	817
	292	342	825	797	385	321	804	790	153	257	814	817
	188	246	830	790	345	330	807	791	150	261	815	817
	294	352	820	783	351	333	810	792	139	261	820	820
	297	352	822	785	358	332	808	792	75	187	839	843
AVERAGE	279	334	824	790	359	338	807	787	140	238	817	820

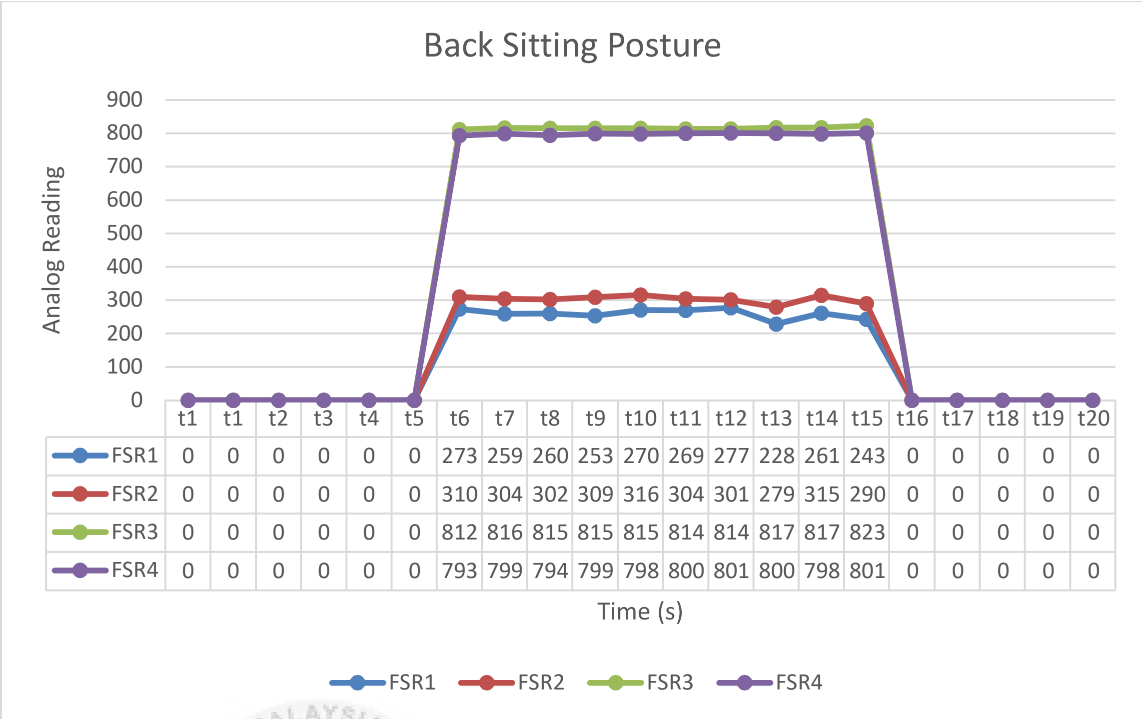


Figure 4.6: Result of Back Sitting Posture

Table 4.3: Front sitting posture

	Experiment 1				Experiment 2				Experiment 3			
	FSR1	**FSR2**	**FSR3**	**FSR4**	**FSR1**	**FSR2**	**FSR3**	**FSR4**	**FSR1**	**FSR2**	**FSR3**	**FSR4**
ANALOG READING	525	504	717	645	417	541	618	593	525	549	661	479
	536	507	715	650	420	516	743	683	458	475	756	574
	538	501	719	644	499	497	765	608	465	499	700	615
	537	505	723	645	446	456	772	695	507	530	741	561
	521	510	727	658	409	397	774	669	494	506	713	593
	584	477	702	690	431	401	777	678	502	510	758	625
	597	460	718	680	379	364	776	691	487	520	749	592
	453	473	780	684	367	356	779	694	413	529	785	612
	448	498	768	689	422	455	785	692	423	539	802	548
	450	501	776	685	442	453	754	680	415	547	803	577
AVERAGE	519	494	735	667	423	444	754	668	469	520	747	578

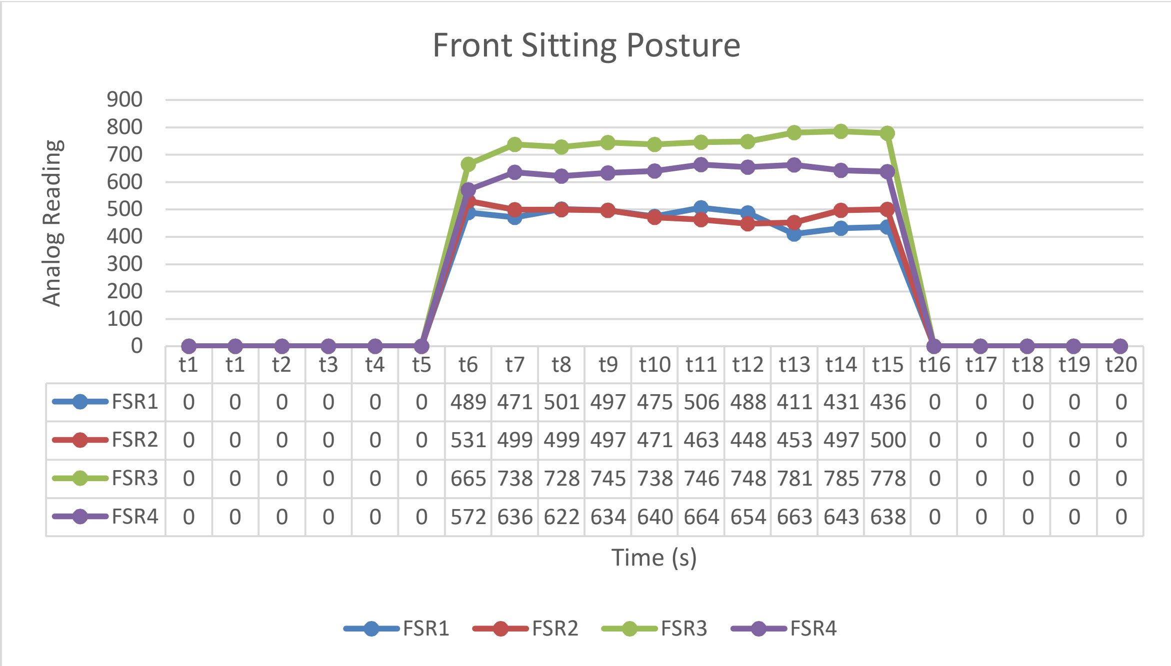


Figure 4.7: Result of Front Sitting Posture

Table 4.4: Right sitting posture

	Experiment 1				Experiment 2				Experiment 3			
	FSR1	**FSR2**	**FSR3**	**FSR4**	**FSR1**	**FSR2**	**FSR3**	**FSR4**	**FSR1**	**FSR2**	**FSR3**	**FSR4**
ANALOG READING	281	248	56	195	172	299	324	261	186	371	302	242
	180	275	344	402	178	282	390	260	131	359	192	283
	98	274	257	328	126	330	333	267	143	350	184	291
	112	263	262	344	78	319	349	288	142	351	193	297
	148	266	289	311	83	318	359	300	143	352	199	297
	137	303	264	291	169	312	371	311	143	350	214	300
	124	302	209	313	137	318	344	306	139	348	212	303
	124	283	278	313	175	347	282	270	140	349	212	304
	127	283	290	321	213	357	286	255	136	350	217	305
	136	285	293	322	220	360	293	265	138	348	219	307
AVERAGE	147	278	254	314	155	324	333	278	144	353	214	293

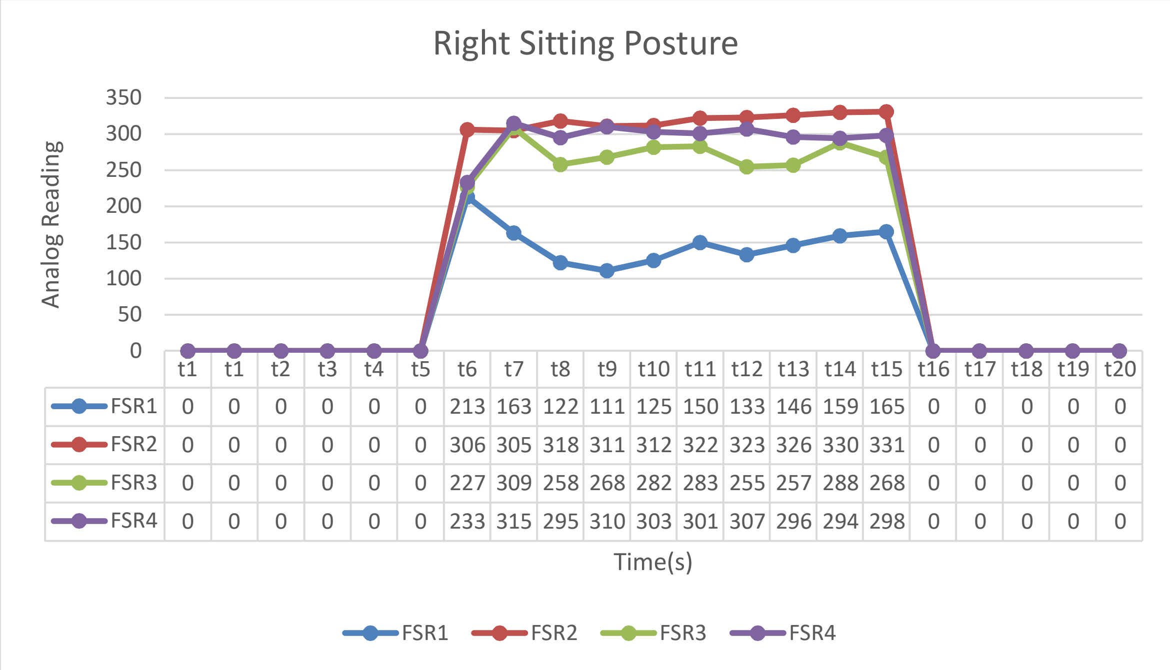


Figure 4.8: Result of Right Sitting Posture

Table 4.5: Left sitting posture

	Experiment 1				Experiment 2				Experiment 3			
	FSR1	**FSR2**	**FSR3**	**FSR4**	**FSR1**	**FSR2**	**FSR3**	**FSR4**	**FSR1**	**FSR2**	**FSR3**	**FSR4**
ANALOG READING	299	213	420	7	291	118	435	6	338	124	416	6
	325	150	378	36	292	143	466	6	337	127	416	6
	347	153	394	25	309	157	477	6	336	132	417	7
	294	167	389	60	353	184	418	6	336	128	417	6
	322	169	368	64	333	191	414	6	342	138	412	6
	342	174	377	46	336	192	417	6	366	145	399	7
	345	177	380	59	338	194	417	6	357	142	355	22
	345	179	386	36	343	196	415	6	331	152	318	124
	346	177	390	41	418	301	86	7	336	155	303	169
	348	178	390	50	361	179	391	7	339	154	313	167
AVERAGE	331	174	387	424	337	186	394	62	342	140	377	520

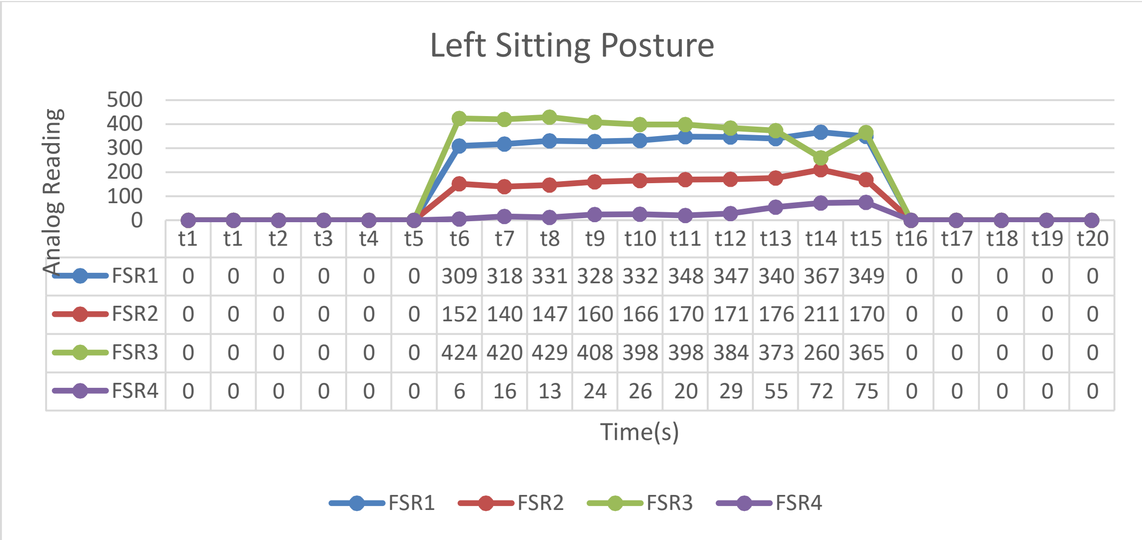


Figure 4.9: Result of Left Sitting Posture

Table 4.6: Overall Result for objective 1

		Mass (Kg)											
		Back			Front			Right			Left		
Experiment	**Force Sensor**	**42**	**51**	**65**	**42**	**51**	**65**	**42**	**51**	**65**	**42**	**51**	**65**
EXP,1	**FSR1**	4	235	279	172	530	519	48	2	147	180	450	331
	FSR2	65	250	334	53	470	494	262	470	278	49	112	174
	FSR3	603	363	824	397	9	735	357	3	254	560	198	387
	FSR4	230	339	790	471	8	667	404	140	314	0	7	424
EXP,2	**FSR1**	20	319	359	57	435	423	0	270	155	416	313	337
	FSR2	0	282	338	54	342	444	9	323	324	0	274	186
	FSR3	469	410	807	386	319	754	0	298	333	741	440	394
	FSR4	380	301	787	393	280	668	450	378	278	0	114	62
EXP,3	**FSR1**	23	320	140	121	466	469	0	290	144	338	326	342
	FSR2	16	309	238	84	412	520	230	343	353	6	260	140
	FSR3	652	428	817	350	270	747	0	324	214	741	477	377
	FSR4	568	330	820	391	220	578	575	387	293	0	70	520

4.2.2.1 Discussion of Four Type of Sitting Posture

Based on the result of the graph and the table, the conclusion can be made by using comparison and threshold value technique. There are three type of sitting postures that can use comparison technique which are back sitting posture, right sitting posture and left sitting posture. All these three type of sitting posture shows same result for all the subjects while front sitting posture produce confusing result and threshold value must be set to indicate front sitting posture at serial monitor. Three subjects with different weight and size body were tested and all the data were taken and tabulate in the table. The graphs' result are taken based on the average line of every each of experiment according to the FSR.

The average value from the Table 4.2 and Figure 4.6, subjects show that back sitting posture has higher analog reading value at FSR3 and FSR4 than FSR1 and FSR2 (FSR3 > FSR1 and FSR4 > FSR2). The average value from the Table 4.4 and the graph Figure 4.8 of Right Sitting Posture also shows that FSR2 and FSR4 more than FSR1 and FSR3 (FSR2 > FSR1 and FSR4 > FSR3) while the average value from Figure 4.9 and Table 4.5 for left sitting posture shows that FSR1 and FSR3 more than FSR2 and FSR4 (FSR1 > FSR2 and FSR3 > FSR4).

These three type of sitting postures can be describe easily by use the comparison technique because the sensors show obvious difference between one another but Front Sitting Posture (FSP) cannot be compared easily by the sensor because the result from Table 4.3 and Figure 4.7 of the FSP, it show analogs value are quite same with back sitting posture's result. So, to describe front sitting posture, threshold value must be set. Take the lowest average analog value of FSR1 and FSR2 that was performed by the subjects. Set it as the threshold value to make the Arduino easy to read the sitting posture.

Overall data of participated subjects are tabulate in Table 4.6. The chair that was built with 4 sensors has higher efficiency but only can read less type of sitting posture and suitable to use for all students that has more than 50 kilogram and lower than 80 kilogram. The result show Arduino can read 4 type of sitting postures very well but the student that has lower than 50 kilogram has some problem with their front and back sitting posture. It is because the weight at their knee while seating is very light and cannot be read clearly.

4.3 Experimental Data (Objective 2)

In this part, there are 2 experiments that were conducted. First experiment is to study the best position of the Force Sensor and the second experiment is conducted to test the efficiency of the prototype. 11 sensors are used to detect 8 type of sitting posture which are leaning back, sitting upright, leaning forward, leaning right, leaning left, right leg crossed, left leg crossed and slouching. All 11 sensors were put in the best position where the muscle of the human hit most while in sitting posture. This experiment use the same concept as objective 1's technique to get the result. 6 students from 42 kilogram to 78 kilogram were participated in this experiment.

4.3.1 Experimental Result for the Best Position of the Force Sensor

Figure 4.10 shows there are 3 Force Sensors at the backseat and 8 Force Sensor at the hipseat. This initial prototype has lower efficiency for leaning back sitting posture. It is because the shape of the human body is difference from one another like bend shape or bend shape. So if the students have the plane body, the sensor cannot detect the body well as the shape of the backseat is in bend shape. So to overcome this problem, Force Sensitive Resistor (FSR) which is FSR6 is changed to the backseat. Position of FSR4, FSR5 and FSR6 also have been changed due to increase the efficiency of leaning right and leaning left sitting posture. The final position of the Force Sensor is shown in figure 4.11 and the connection of the completed Force Sensor is shown in Figure 4.12. Figure 4.14 shows the different position of sitting posture conducted by the subject.

Figure 4.10: Initial position of the force sensor

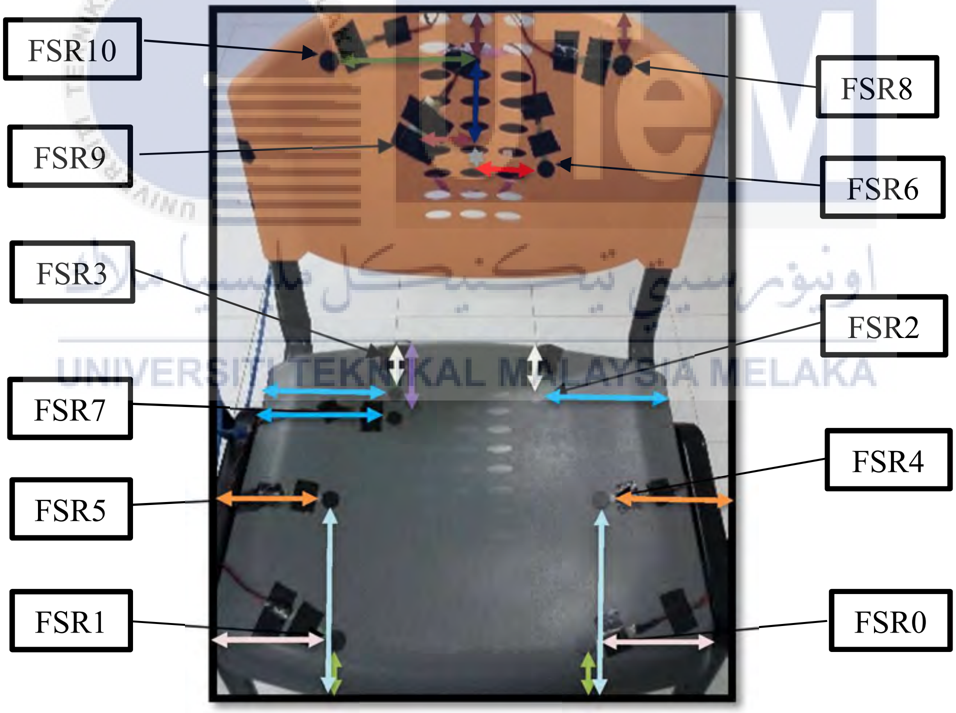


Figure 4.11: Final position of the Force Sensor

Table 4.7: Measurement Detail for prototype objective 2

Colour	Distance (Cm)
	10.5
	8.5
	12.1
	9
	6.6
	3.8
	2
	13
	5.5
	14.2
	5
	11
	13.2

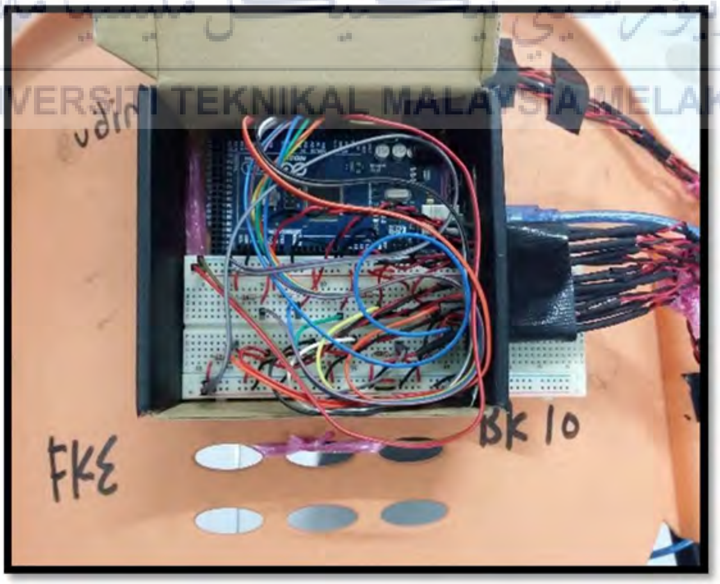


Figure 4.12: Connection of the completed Force Sensor

Figure 4.13: Prototype of the project

The final position of the Force Sensor will be covered by the cloth as shown in figure 4.13. This is to make sure the students feel comfortable when seat on the chair instead of see the wire of the Force Sensor. It also will give comforts to the students while sitting because the cover is to decrease the hard seat.

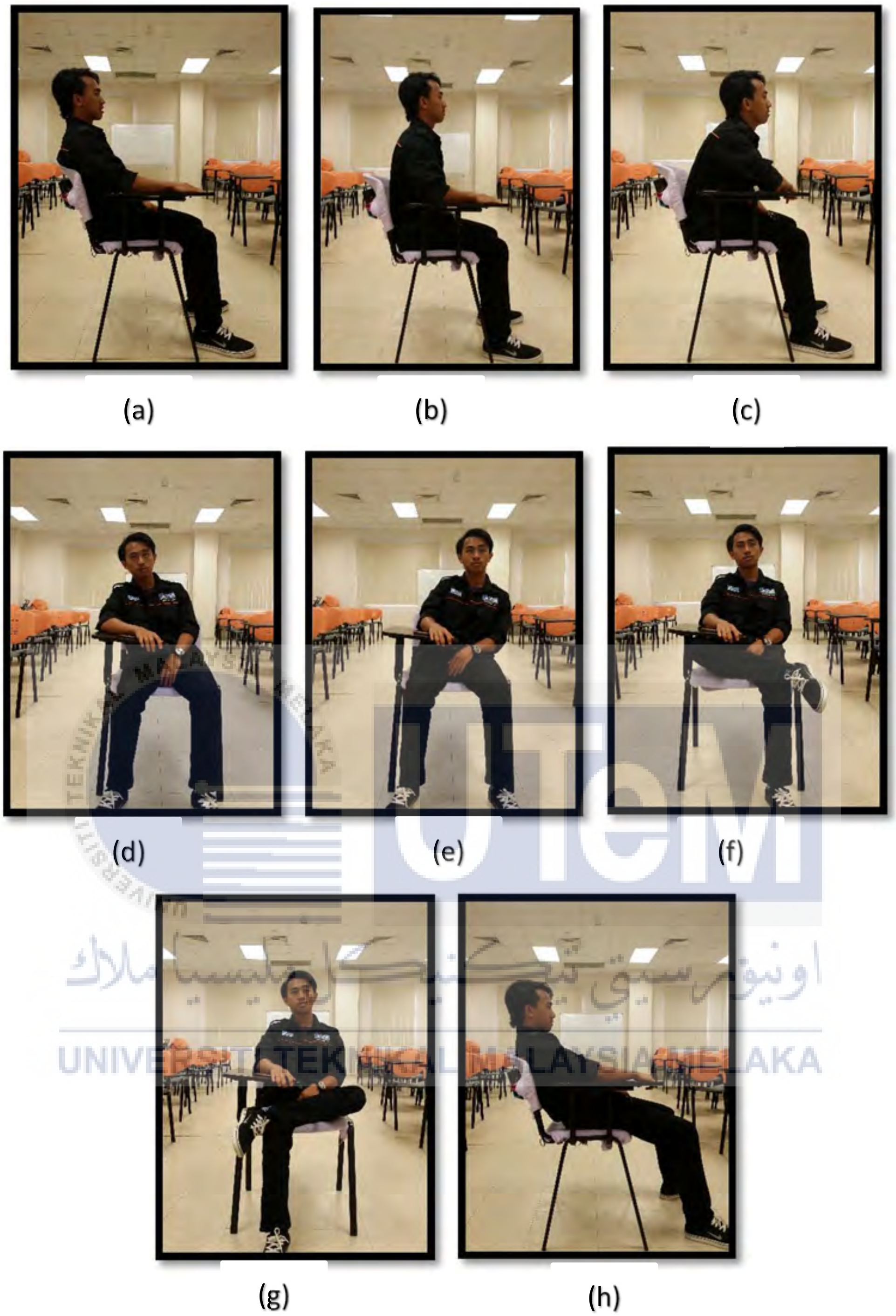


Figure 4.14 (a): Leaning Back. (b): Sitting Upright. (c): Leaning Forward. (d) Leaning Right. (e): Leaning Left. (f): Right leg Crossed. (g): Left Leg Crossed. (h) Slouching.

4.3.2 Experimental Result for the Efficiency of the Prototype

Figure 4.15 until figure 4.20 show the efficiency of different type of sitting posture based on different weight of the subjects. Figure 4.21until figure 4.28 show the relationship of the different type of sitting posture by comparing the different weight of subjects.

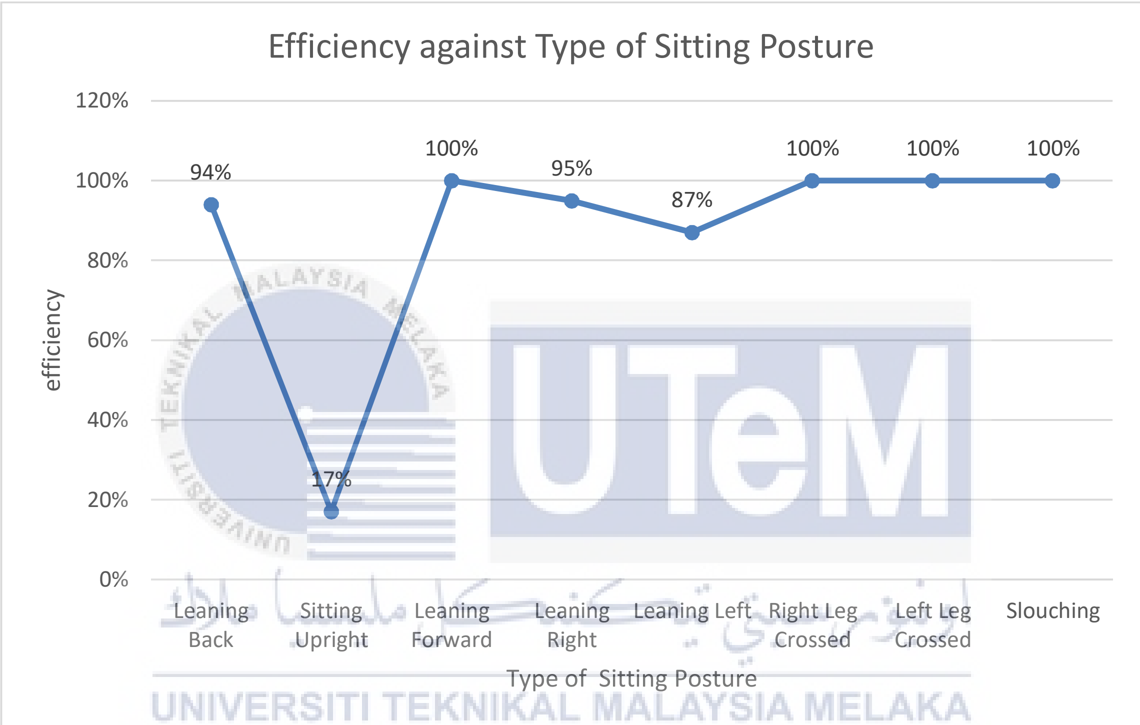


Figure 4.15: Subject (42 Kilogram)

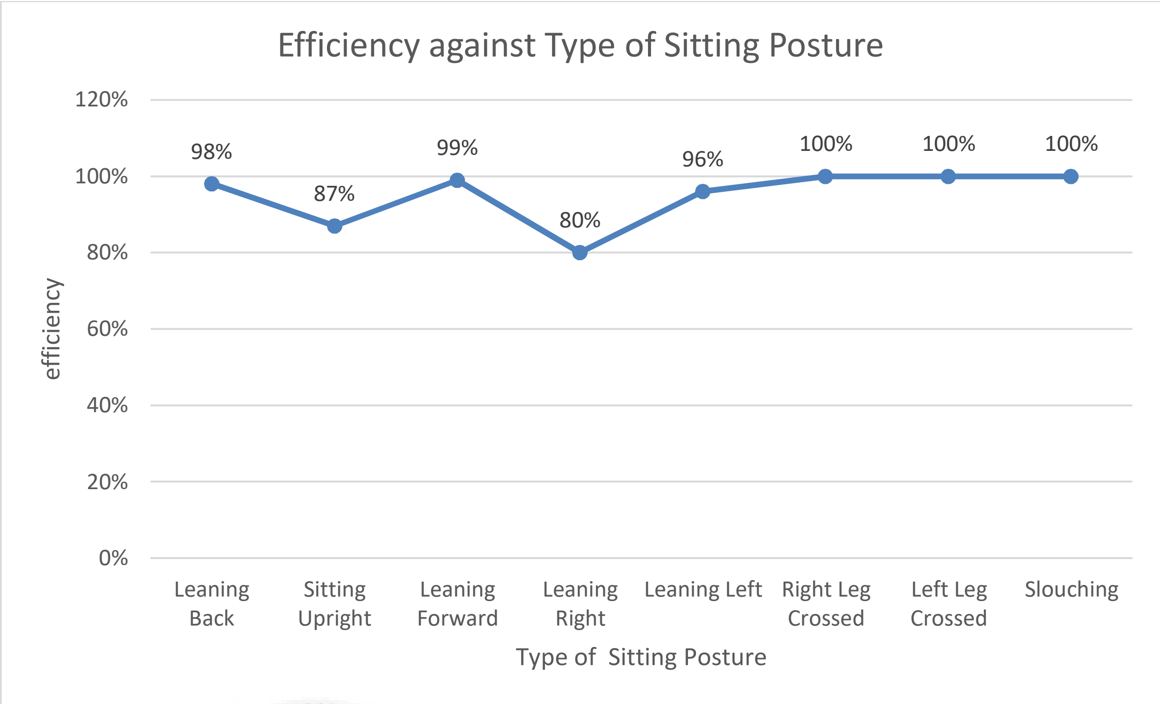


Figure 4.16: Subject (50 Kilogram)

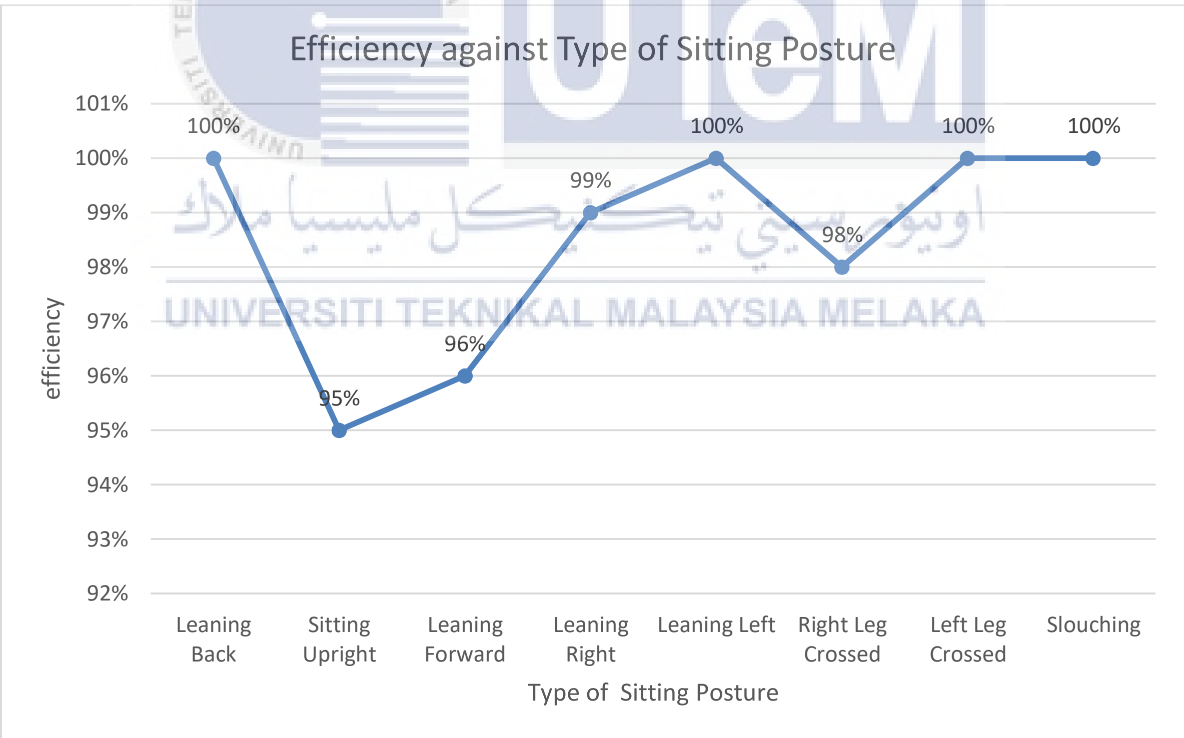


Figure 4.17: Subject (60 Kilogram)

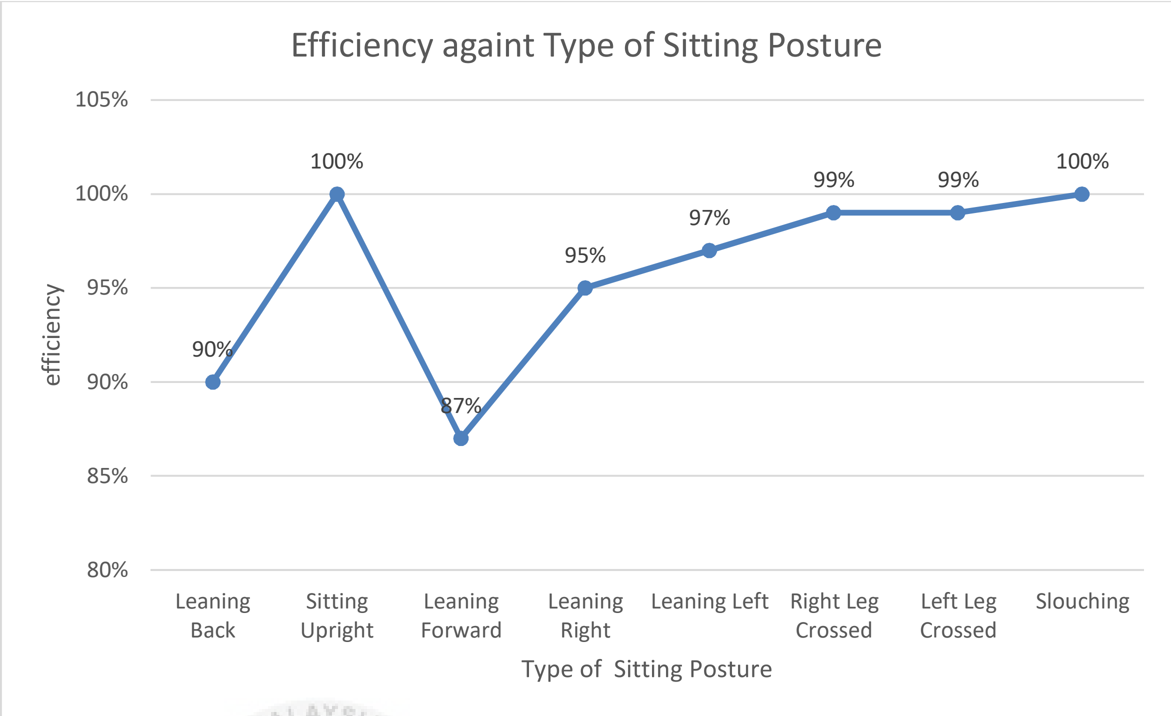


Figure 4.18: Subject (61 (Kilogram)

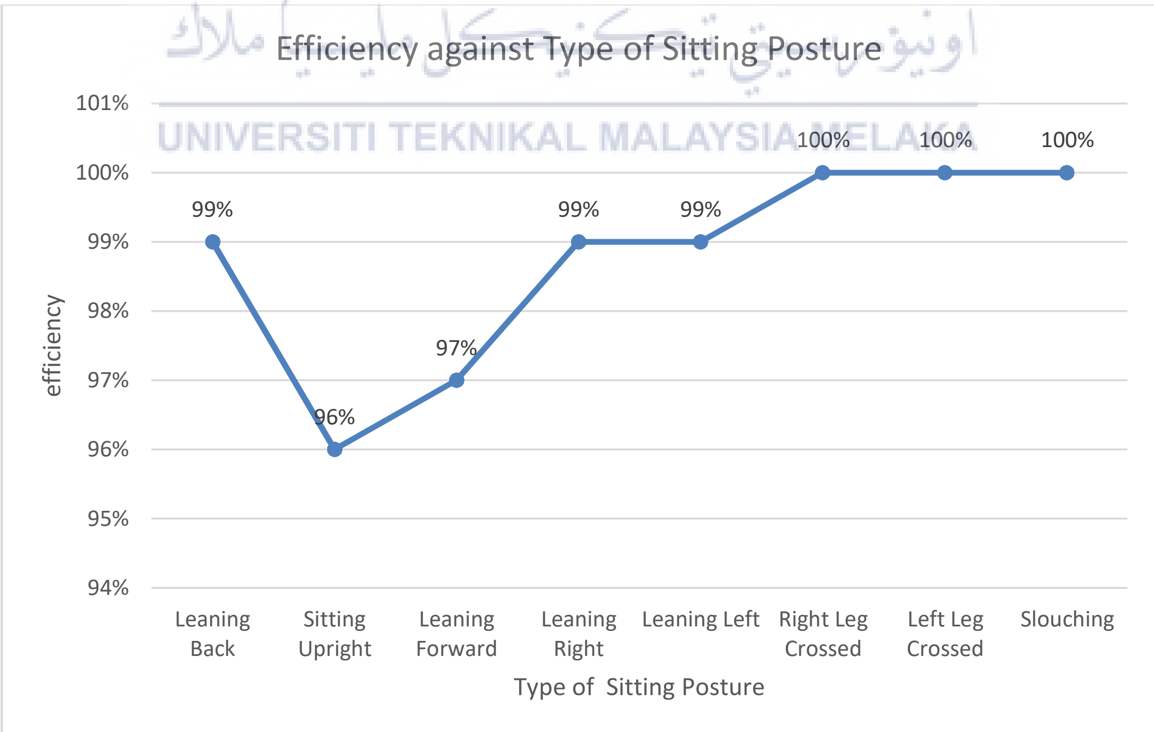


Figure 4.19: Subject (65 Kilogram)

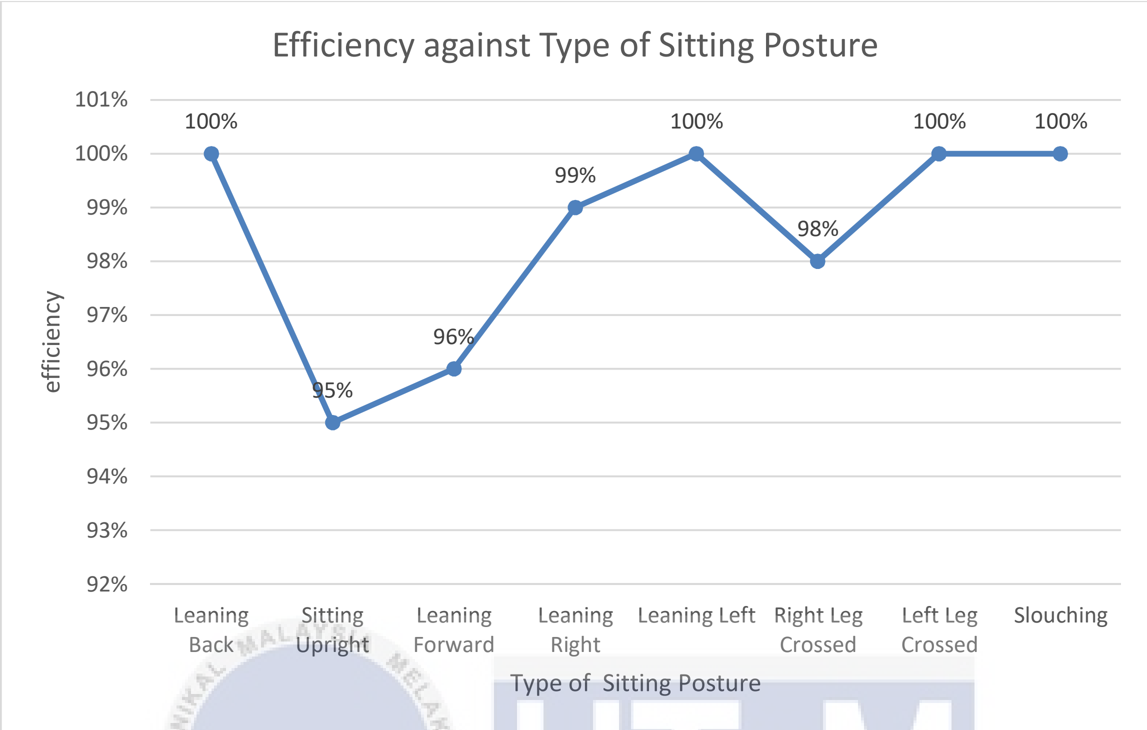


Figure 4.20: Subject (78 Kilogram)

Figure 4.15 shows the result of the subject with 42 Kilogram and 162 cm height. From the data appeared, the result for the leaning back sitting posture is not very satisfied. According to the shape of the seat, the sensor cannot detect very well with the size of the subject's body. The result of seated upright also is not satisfied as others sitting posture. Sitting upright posture shows it more to leaning forward form. This is due to the high weight at the leg than the upper body. So, if the subject in a leaning forward position, the sensor can detect 100% because the weight at the leg is good enough. For leaning right and leaning left sitting posture, the number of sensor at that part(left and right of the chair) is not high enough to get 100% data but the result for the remaining sitting posture which are right leg crossed, left leg crossed and slouching are well enough and have high efficiency.

Figure 4.16 shows the result of the subject with 50 Kilogram and 163 cm height. From the data appeared, the result for the leaning back sitting posture almost hit the target which is 100 but the result for sitting upright is the second lowest compared with other sitting postures. It is because the weight at the hip is not heavy than the weight at the leg. Sitting upright posture shows it more to leaning forward form. This is due to the high weight at the leg than the upper body. So, if the subject in a leaning forward position, the sensor can detect almost 100% same with the subject with 42 Kilogram.. For leaning right and leaning left sitting posture, the number of sensor at that part(left and right of the chair) is not high enough to get 100% data but the result for the remaining sitting posture which are right leg crossed, left leg crossed and slouching are well enough and have high efficiency.

Figure 4.17 shows the result of the subject with 60 Kilogram and 180 cm height. From the data appeared, the result for the leaning back, right leg crossed, left leg crossed and slouching are well enough and have high efficiency is 100% while the result of Seated upright is the lowest compared to other sitting posture. When the subject is seated upright, the data that was shown is 95% and when the subject seat in leaning forward form, the leg of the subject sometimes more higher than the chair. So, it will effect the data when the subject performed leaning forward posture. For leaning right and leaning left sitting posture, the number of sensor at that part(left and right of the chair) is not high enough to get 100% data but the result is very precise with this weight and height.

Figure 4.18 shows the result of the subject with 61 Kilogram and 164 cm height. From the data appeared, the result for leaning back sitting posture is 90%. When the subject is in leaning back posture, sometimes it show the subject is in seated upright. So, for the sitting upright posture, it show the efficiency of the chair is 100% while leaning forward 87%. According to the shape of the seat, the sensor cannot detect very well with the size of the subject's body when in both leaning back and leaning forward sitting posture. For the remaining type of sitting posture, most of the results are 95% and above.

Figure 4.19 shows the result of the subject with 65 Kilogram and 171 cm height. From the data appeared, all the results are 96% and above. The lowest efficiency is when the subject performed seated upright sitting posture which is 96% and the second lowest is 97% which is leaning forward. According to these results, the weight and the height of the subject is suitable to run the objective 3 experiment.

Figure 4.20 shows the result of the subject with 78 Kilogram and 175 cm height. Sitting upright and leaning forward show 95% and 96% efficiency. Leaning back, leaning left, left leg crossed and slouching show 100% efficiency while the result for leaning right and left leg crossed are 99% and 98%. This is the first time the result of the Right leg crossed is not achieve 100%. From what have been observed, the sensitivity of the sensor it not in good condition thus it effect the result of left leg crossed.

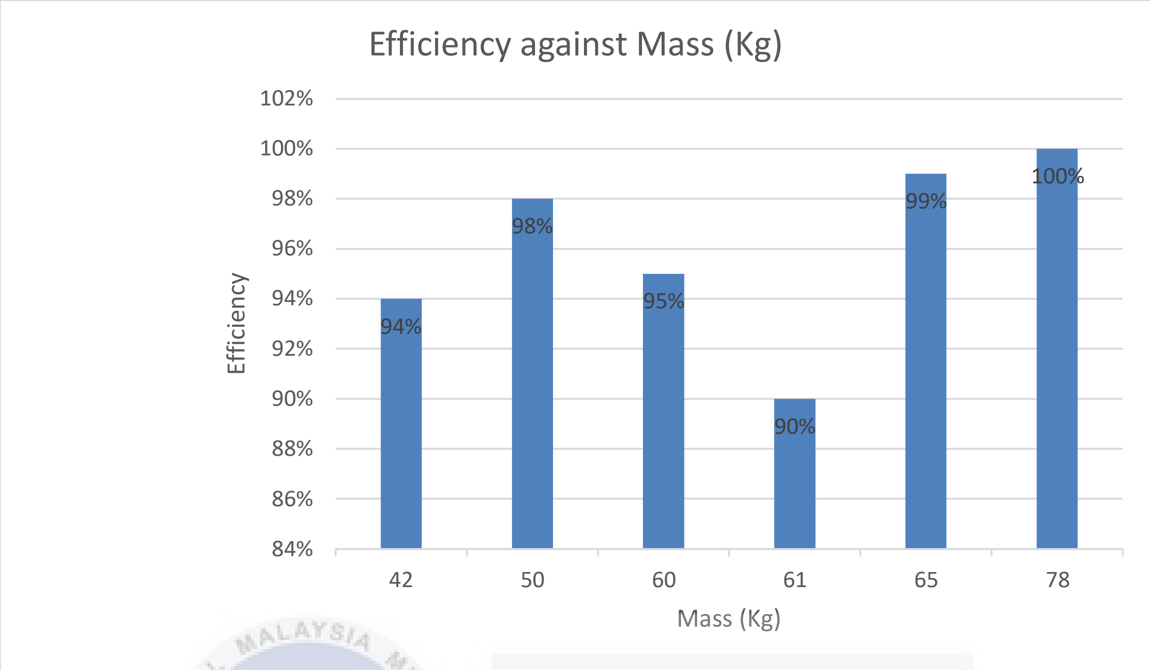


Figure 4.21: Leaning Back Sitting Posture

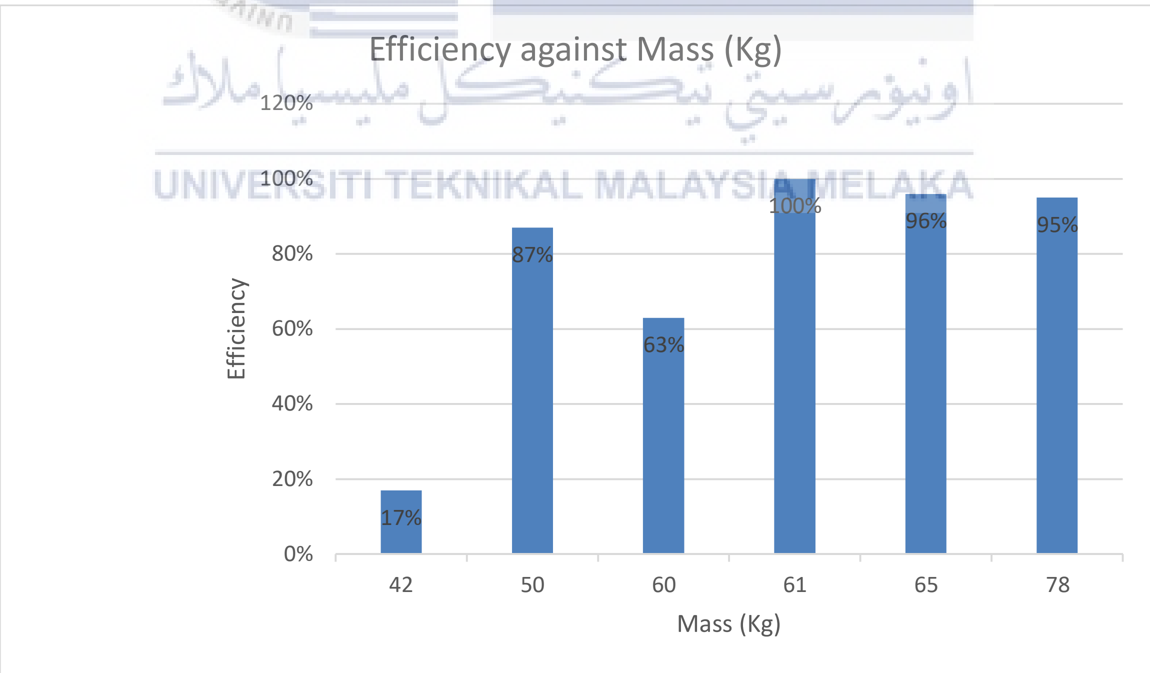


Figure 4.22: Sitting Upright Sitting Posture

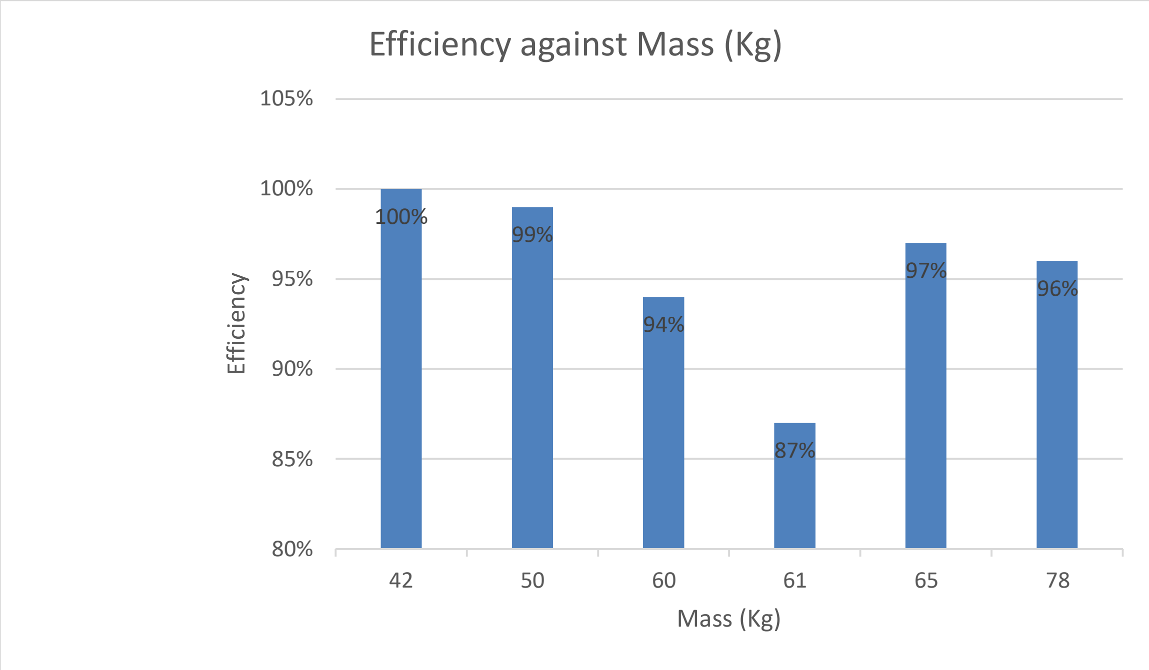


Figure 4.23: Leaning Forward Sitting Posture

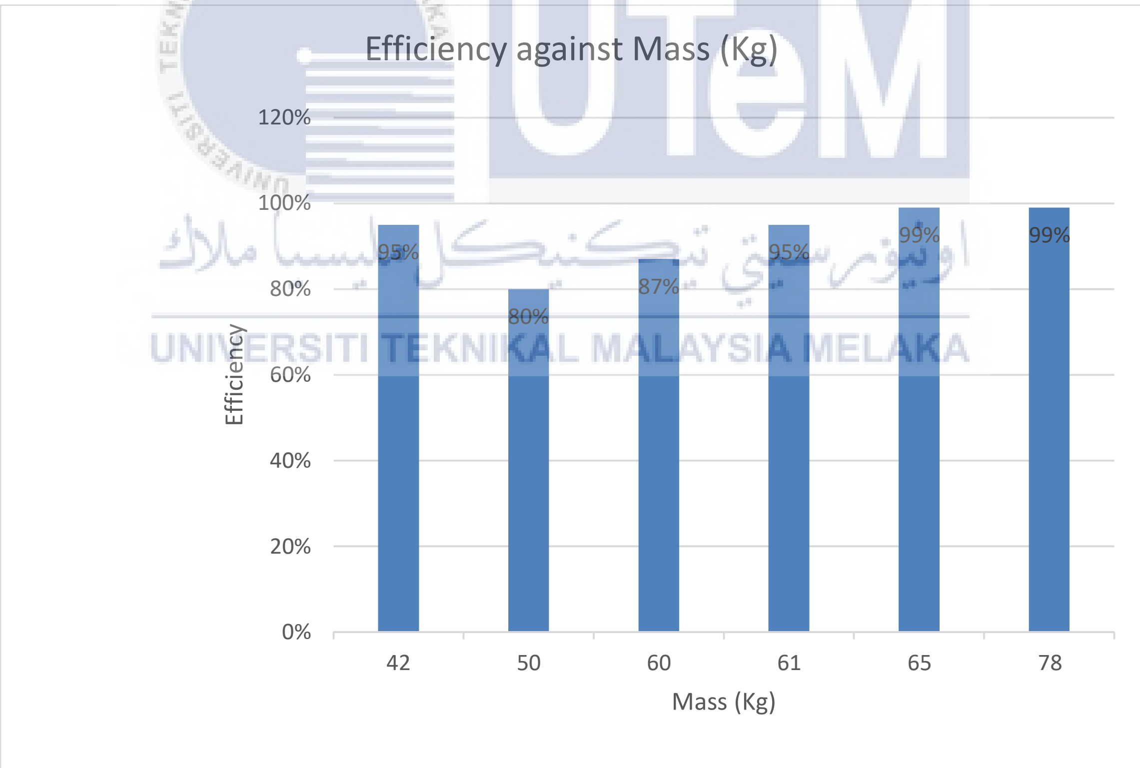


Figure 4.24: Leaning Right Sitting Posture

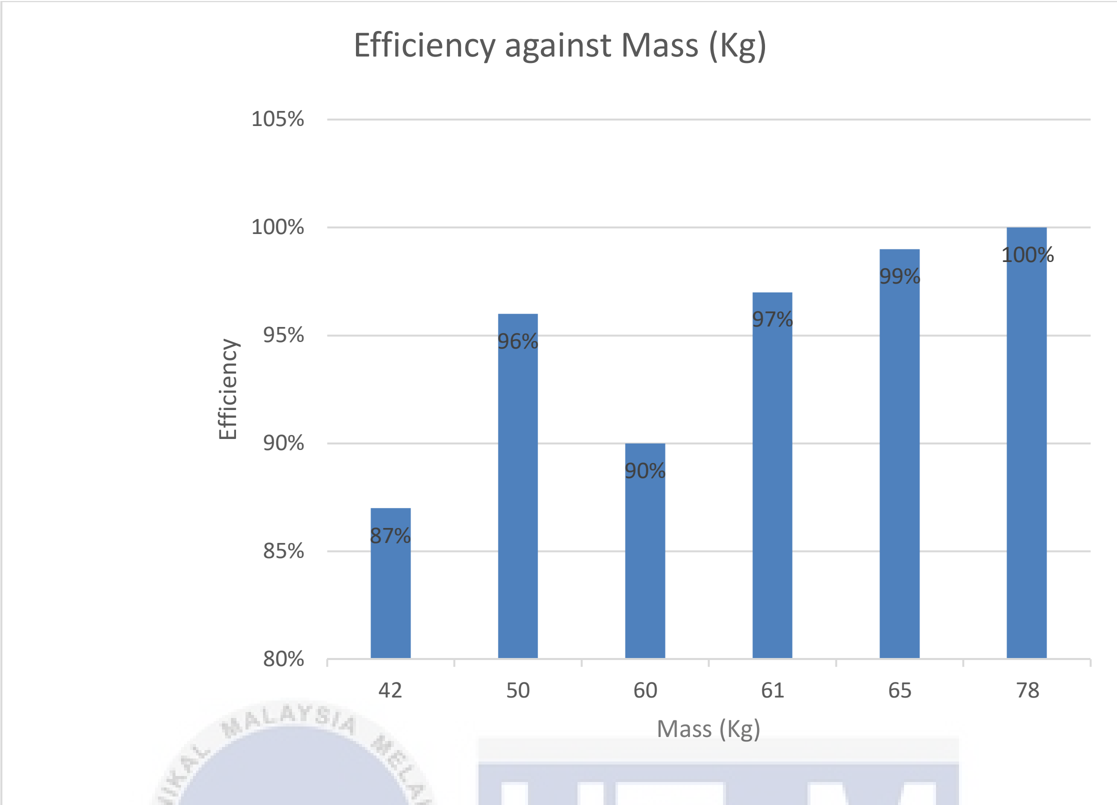


Figure 4.25: Leaning Left Sitting Posture

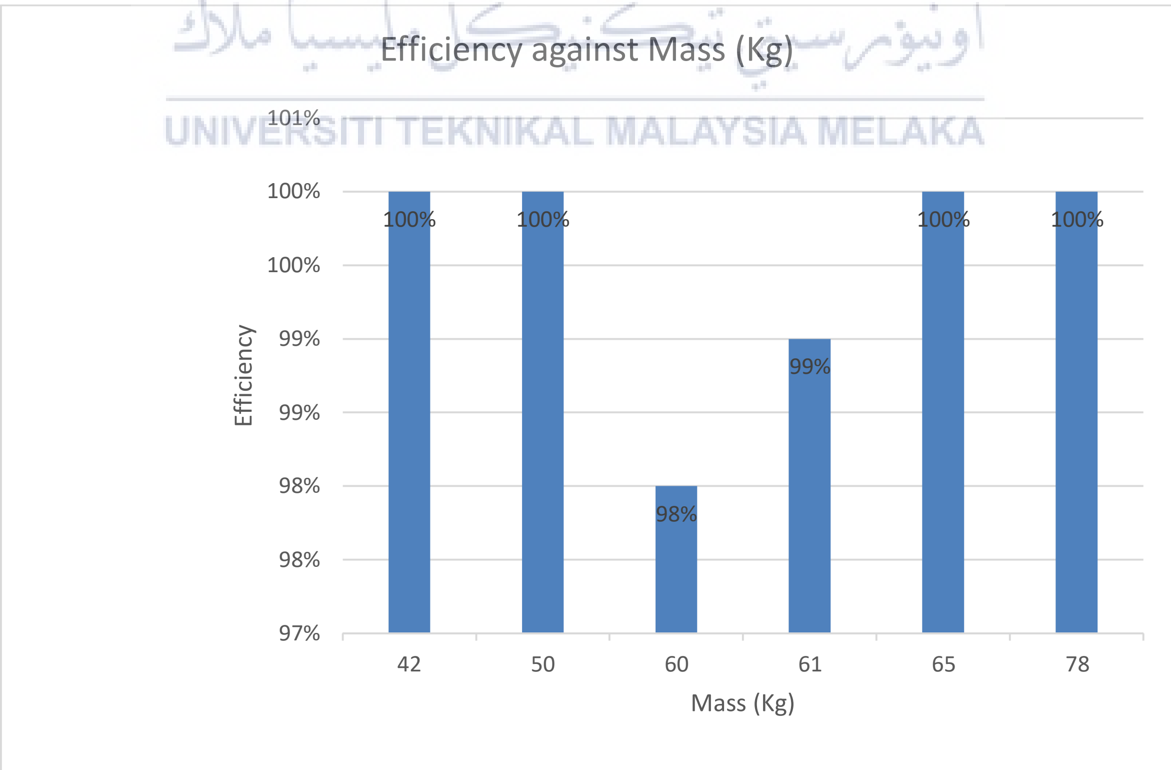


Figure 4.26: Right Leg Crossed Sitting Posture

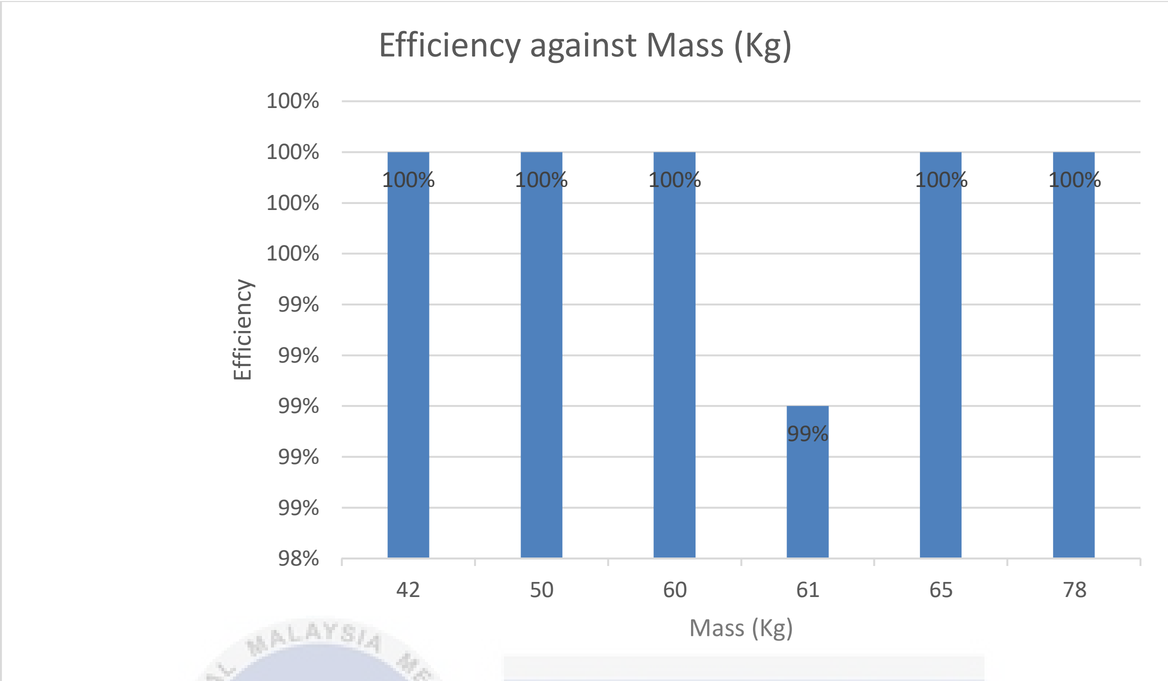


Figure 4.27: Left Leg Crossed Sitting Posture

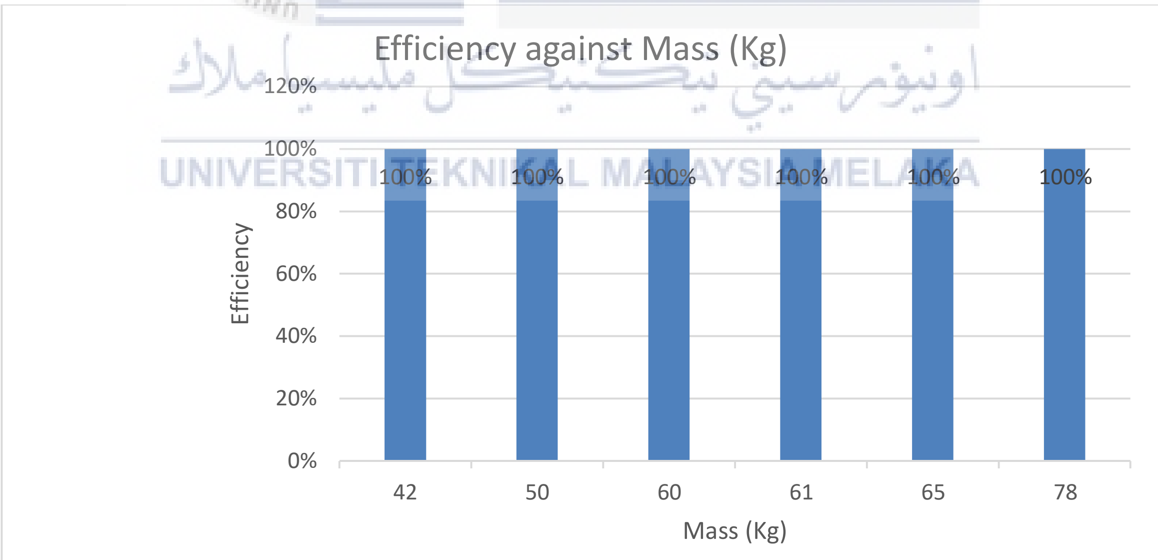


Figure 4.28: Slouching Sitting Posture

Figure 4.21 until figure 4.28, it shows the bar graph of the efficiency against mass of the subjects. The highest efficiency for back sitting is the student with the mass 78 Kg which is 100% while the lowest efficiency for leaning back is the students with mass 61 Kg which is 90%. Figure 4.22 shows the efficiency of sitting upright sitting posture where the efficiency is 100% when 61 Kg of students sit on it and will become lowest which is 17% if 42 Kg student sit on it. In Figure 4.23, the highest efficiency of upright sitting posture is 100% for 42 Kg student and the lowest efficiency is 87% for 61 Kg student.

Figure 4.24 shows the efficiency is highest for 65 Kg and 78 Kg students which is 99% while the lowest efficiency is 80% for 50 Kg student. For leaning left sitting posture, the highest efficiency is 100% for 78 Kg student while the lowest is 87% for 42 Kg student. Figure 4.26 shows 60 Kg and 61 Kg student that do not perform 100% when in right leg crossed sitting posture while Figure 4.27 only 61 Kg student do not perform 100% which is 99% efficiency. In Figure 4.28, the all the results are 100% efficiency.

4.3.3 Discussion of the Efficiency

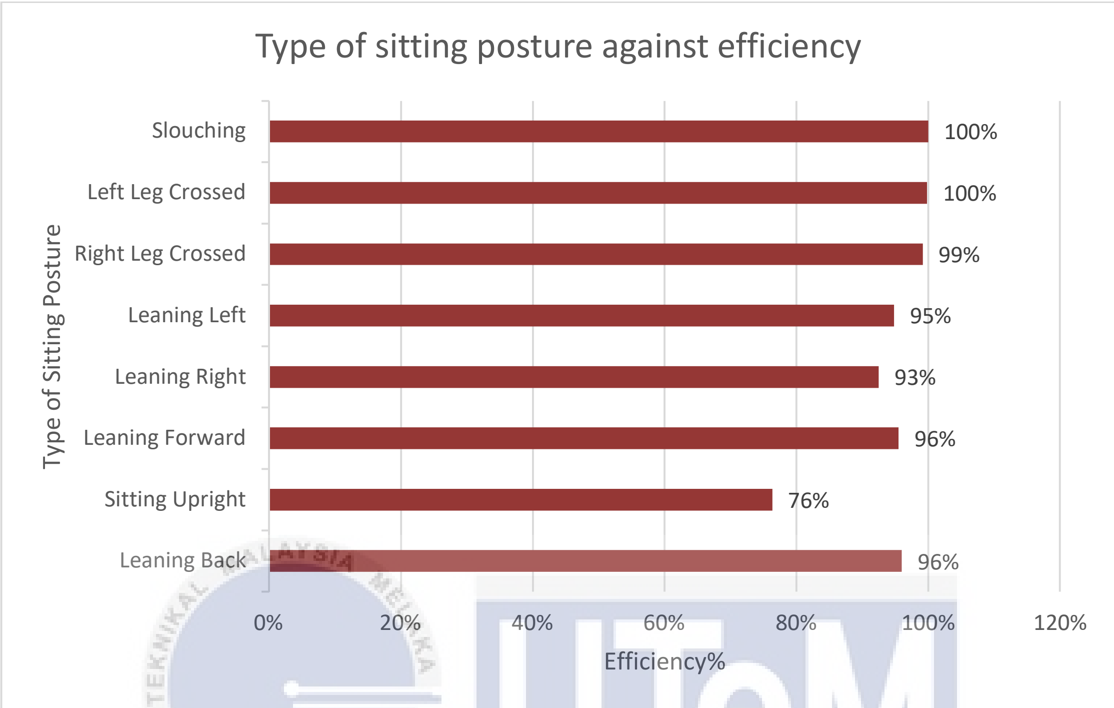


Figure 4.29: Prototype's Efficiency

Figure 4.29 shows the graph of the prototype's efficiency percentage for all type of sitting postures from 42 Kg to 78 Kg. The result of the efficiency is plotted by the average efficiency from all subjects. 2 type of sitting postures got 100% which are slouching and left leg crossed while right leg crossed show 99%. Leaning back and leaning forward show 96% efficiency, leaning left 95%, leaning right 93% and lastly seated upright which is 76%. All of the sitting postures are 90% above but only one below than 90%. The loss of 1 to 2 percent of efficiency usually come from technical problem like low sensitivity of the sensor. As conclusion, the objective to identify the suitable position of the sensor with minimum amount of sensors is success and can proceed to objective 3.

4.4 Experimental Data (Objective 3)

In this section, the experiment will be held at the classroom environment. The prototype from objective 2 is use in this section to get the data of sitting posture that will done by the students.

4.4.1 Experimental Result for the relationship between sitting posture and focus of the students

Table 4.8: Result of Multiple Choice question

	Student A	Student B	Student C	Student D	Student E
Engineering Ethic	3/5	3/5			
Entrepreneurship	4/5	5/5	5/5	3/5	
Data Communication	4/5	2/5	4/5	3/5	2/5

11 students were chose to participate in this experiment. The result were taken from different subjects which are Data Communication, Engineering Ethic and Entrepreneurship. Type of question that will be ask is only multiple choice questions and each student will be given 5 question to answer based on their sitting posture. The others question also will be asked if the same student seat in same type of sitting posture. If the students answer correctly meaning that they are in focus mode while if they answer wrongly meaning that they are not focus. Students A, B, C, D and E for every courses are different students.

Two students were involved in the experiment for Engineering Ethic. The result shows student A and student B only can answer 3out of 5 question. Student A were answer correctly while he seats in leaning back(LB), sitting upright(SU) and slouching(S) while the answer were wrong when he is in LB and left leg crossed(LLC). Student B also can answer correctly when he is in leaning forward(LF), LLC and LB but made mistake when in slouching and also LB.

4 students were participated in the experiment for Entrepreneurship's course. Student A only can answer 4 out of 5 question. Student A answer correctly when he seats in leaning left(LL), LB, LF, and RLC while wrong even he in RLC. Student B and C answer perfectly (5/5) in all question which are student B in LB, leaning right(LR), LF, RLC and LLC while student C in LB, S, RLC, RLC and LLC. Student D is focus when he in LB, LR and LL but did not focus when in LB and RLC.

5 students were participated in the experiment for Data Communication's course. Student A and C can answer correctly when in LB, SU, LL and RLC but incorrectly when in LR and LF. Student B only can answer correctly when he in RLC and LB while incorrectly when in RLC, LF and slouching. Student D only focus when in slouching, LB and LR while incorrectly when in LB and LLC. Student E can answer correctly when in SU and LLC and incorrectly when in slouching, Leaning Forward and leaning left.

As conclusion, overall student that had been participated are focus 10 out of 14 when in leaning back sitting posture, 4/4 in sitting upright, 3/6 in leaning forward, 3/4 in leaning right, 4/5 in leaning left, 7 out of 10 when in right leg crossed, 4 out of 6 in left leg crossed and 3/6 when in slouching sitting posture.

4.4.2 Discussion of the Relationship between Sitting Postures and Focus of the students

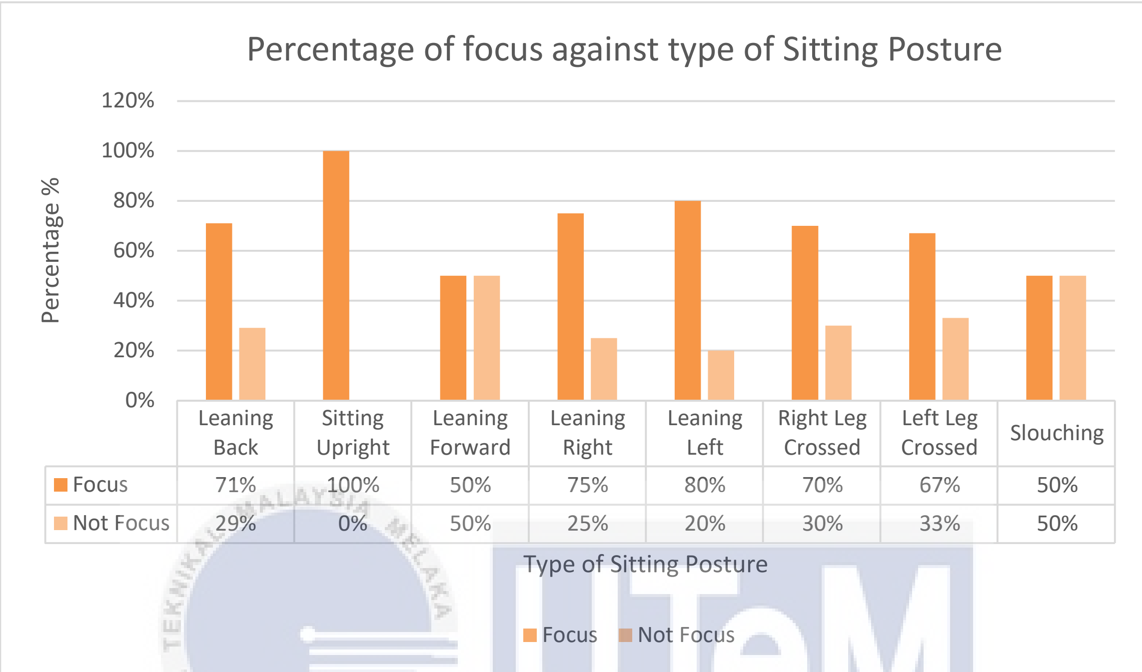


Figure 4.30: Relation between type of Sitting Posture and Focus

Graph above shows the focus of the students are 100% when they seated in sitting upright sitting posture. The percentage of the focus is same which are 50% when students are in leaning forward and slouching sitting posture. The result also shows students focus is high when in leaning back sitting posture which is 71% while 29% is not focus. Leaning right and leaning left show almost same result which are students will focus until 75% and 80% while 25% and 20% will interrupt the student's focus. Lastly, the result for student's focus also almost same which is will up until 70% when they are in right leg crossed and 67% in left leg crossed. While 30% and 33% will cause the students do not focus while learning in the class.

CHAPTER 5

CONCLUSION & RECOMMENDATION

In this section, a conclusion based on what already done during FYP1 and FYP2 will be discussed. Besides, recommendation which deals with the continuation of the Investigation of Sitting Posture will also be added in this chapter.

5.1 Conclusion

The first objective which is to analyse sitting posture of the students by using Force Sensitive Resistor is achieved. Two experiments were conducted in this first objective which are to test the sensitivity of the sensor and to analyse students sitting posture. The first experiment is achieved when the result of the sensitivity of the sensor is directly proportional to the reading of the Force Sensor. It is to make sure the reading for the next experiment do not have any error while it is conducted. Second experiment which is to analyse four type of sitting posture which are back, front, right and left also have been achieved by using 4 sensors.

To achieve the second objective which is to design and identify the suitable position of the sensor with minimum amount of sensors, the development of the prototype has been released. All eight type of sitting posture that has been stated in objective 2 is able read by the prototype correctly. The efficiency of the prototype also has been tested in this objective

2 and the result of all the efficiency is above 75% and satisfied enough to proceed to objective 3.

The third objective which is to relate the relationship between students' sitting posture and focus in classroom environment is achieved. The experiment to relate the relationship between the sitting posture and focus has been conducted in classroom environment in three different courses which are Engineering Ethic, Data Communication and Entrepreneurship. The results were taken based on the test that answered by the students and the relationship between sitting postures and focus of the students have been finalized.

5.2 Recommendation

For the future recommendation, the electronic chair that will build must be able to measure all type of sitting postures. To measure the sitting postures, it is recommended that the amount of the force sensor is enough and must hit the muscles of the subject because it will give an accurate value of the force sensor. If the amount of Force Sensitive Resistor is enough, the comparison between force sensors can be seen clearly and it will make the future researchers easy to do pressure mapping and relate it with the bad sitting posture. So, it is easy to determine the sitting posture based on the measured value.

For the future work, it is also recommended to continue my research of Final Year Project which is how to relate the focus of the student with their type of sitting posture. So the result can be compared with the existing result. After all type of sitting posture has been able to be describe, it is suggested to implement any sort of things like buzzer that will make the user alert when they seats incorrectly. So the users can change their sitting posture to be more focus.

REFERENCES

[1] J. E. Estrada, and L. A. Vea, "Real-Time Human Sitting Posture Detection Using Mobile Devices," *IEEE Region 10 Symposium (TENSYMP)*, pp 140-144, 2016.

[2] B. W. Lee, and H. Shin, "Feasibility Study of Sitting Posture Monitoring Based on Piezoresistive Conductive Film-Based Flexible Force Sensor," *IEEE SENSORS JOURNAL*, JANUARY 1, 2016, VOL. 16, NO. 1, pp 15-16.

[3] B. Ribeiro, H. Pereira, R. Almeida, A. Ferreira, L. Martins, C. Quaresma, and P. Vieira, "Optimization of Sitting Posture Classification Based on User Identification," *IEEE 4th Portuguese BioEngineering Meeting Porto*, 26-28 February 2015.

[4] L. Shu, X. Tao, and D. D. Feng, "A New Approach for Readout of Resistive Sensor Arrays for Wearable Electronic Applications," *IEEE SENSORS JOURNAL*, JANUARY 2015, VOL. 15, NO. 1, pp 442-452.

[5] S. Suzuki, M. Kudo, and A. Nakamura, "Sitting Posture Diagnosis Using a Pressure Sensor Mat,".

[6] Y. TAGUCHI1, D. HIRASHIMA1, M. NISHIYAMA1, T. KON2, and K. WATANABE12, "Sensitive Cushion Based on Hetero-core Fiber Optics for

Unconstraint Sitting Posture Monitoring," *IEEE 3rd Global Conference on Consumer Electronics (GCCE)*, pp 640-642, 2014.

[7] M-C. Huang, N. Amini, L. He, and M. Sarrafzadeh, pp 3926-3934.

[8] Y-R. Huang, and X-F. Ouyang, "Sitting Posture Detection And Recognition Using Force Sensor," *5th International Conference on BioMedical Engineering and Informatics (BMEI 2012)*, pp 1117- 1121, 2012.

[9] B. Mutlu, A. Krause, J. Forlizzi, C. Guestrin, J. Hodgins, "Robust, Low-cost, Non-intrusive Sensing and Recognition of Seated Postures," October 7–10, 2007.

[10] Arduino Mega [online] Available at:

https://www.robotics.org.za/index.php?route=product/product&product_id=80 [accessed 25 November 2016]

[11] Force Sensing Resistor [online] available at:

https://www.elprocus.com/force-sensing-resistor-technology/ [accessed 25 November 2016]

[12] B. Hojat, and E. Mahdi, "Effect of different sitting posture on pulmonary function in students," *Journal of Physiology and Pathophysiology*, 2011.

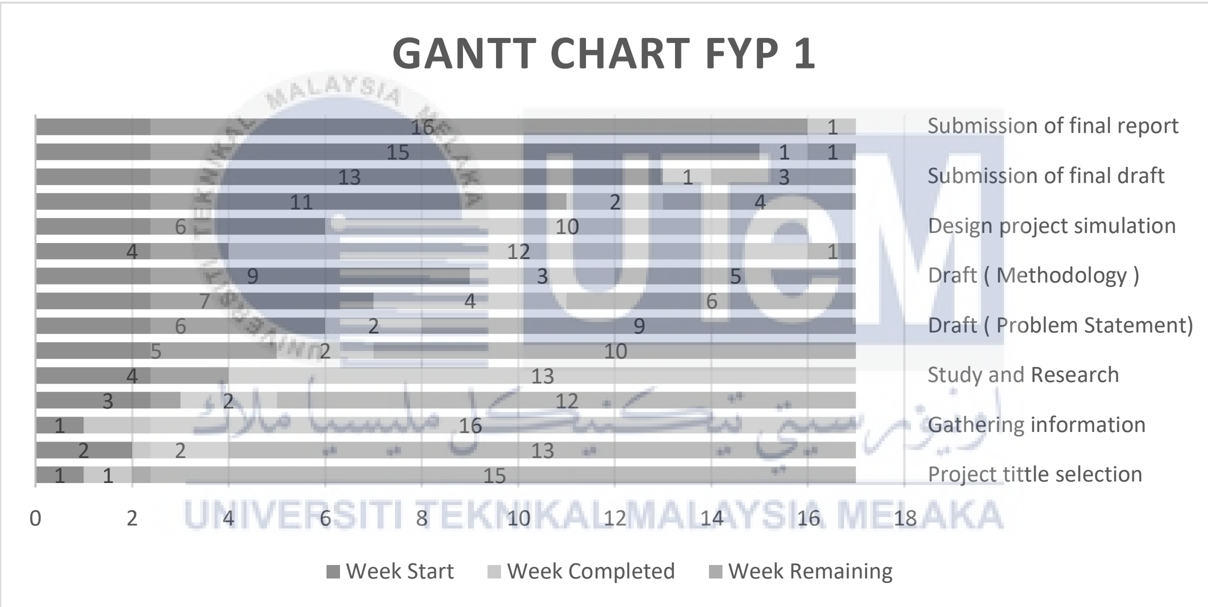
[13] McKinley Health Center University of Illinois. (2008). Posture and Study Habits Guide. [1]

[14] L. Saarni, C-H, Nygard, A. Rimpela, T. Nummi, and A. Kaukiainen, "The WorkingPostures Among Schoolchildren-A Controlled Intervention Study on the Effects of Newly Designed Workstations," *The Journal of School Health*, 2007.

[15] Haruna Ishimatsu, Ryoko Ueoka, "Development of Self Posture Adjustment System," Mar 07-09 2014.

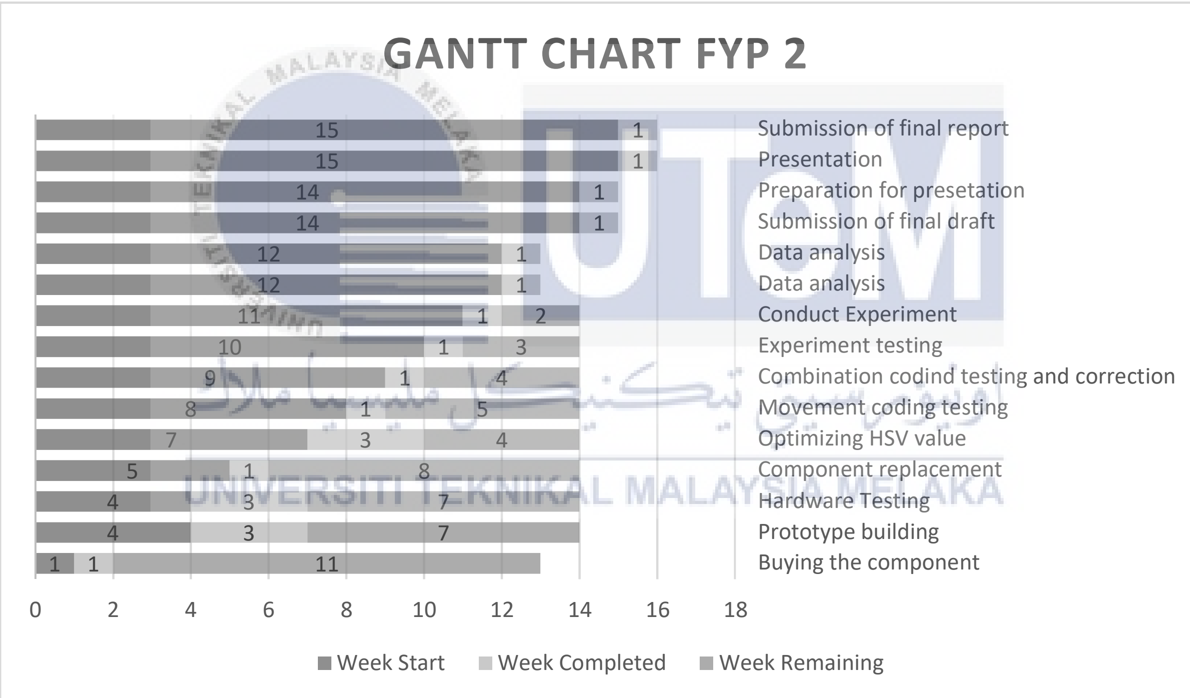
APPENDIX A

Gantt Chart for FYP1



APPENDIX B

Gantt chart for FYP2



APPENDIX C

Coding (Objective 1)

```
int fsr0,fsr1,fsr2,fsr3;

void setup(void) {

Serial.begin(9600);

}

void loop(void) {

fsr0 = analogRead(0);

fsr1 = analogRead(1);

fsr2 = analogRead(2);

fsr3 = analogRead(3);


Serial.print("Analog reading = ");

if (fsr0 < fsr2 && fsr0 < fsr3 && fsr1 < fsr2 && fsr1 < fsr3) {

Serial.println(" - back");

} else if (fsr0 > X && fsr1 > X && fsr2 < Y && fsr3 < Y) {
```

```
Serial.println(" - front");
} else if (fsr0 > fsr1 && fsr2 > fsr3 && fsr2 > fsr1) {
  Serial.println(" - left");
} else if (fsr1 > fsr0 && fsr3 > fsr2 && fsr3 >fsr0) {
  Serial.println(" - right");
} else if (fsr0 < 1000 && fsr1 < 1000 && fsr2 < 1000 && fsr3 < 1000) {
  Serial.println(" - none");
}
delay(1000);
}
```

APPENDIX D

Coding (Ojective 2)

```
int fsr0,fsr1,fsr2,fsr3, fsr4,fsr5,fsr6,fsr7,fsr8,fsr9,fsr10;

void setup(void) {

Serial.begin(9600);

}

void loop(void) {

fsr0 = analogRead(0);

fsr1 = analogRead(1);

fsr2 = analogRead(2);

fsr3 = analogRead(3);

fsr4 = analogRead(4);

fsr5 = analogRead(5);

fsr6 = analogRead(6);

fsr7 = analogRead(7);

fsr8 = analogRead(8);
```

```
fsr9 = analogRead(9);

fsr10 = analogRead(10);

Serial.print("Analog reading = ");

if (fsr0 < fsr2 && fsr0 < fsr3 && fsr1 < fsr2 && fsr1 < fsr3 && fsr9 > 0) {

Serial.println(" - leaning back");

} else if (fsr2 < fsr0 && fsr3 < fsr0 && fsr2 < fsr1 && fsr3 < fsr1 && fsr9 > 0 && fsr2 >
0 && fsr3 > 0) {

Serial.println(" - leaning back");

} else if (fsr2 < fsr0 && fsr3 < fsr0 && fsr2 < fsr1 && fsr3 < fsr1 && fsr4 > 0 && fsr2 >
0 && fsr3 > 0) {

Serial.println(" - leaning back");

} else if (fsr0 > 400 && fsr1 > 400 && fsr2 < 900 && fsr3 < 900 && fsr2 > 0 && fsr3 >
0 && fsr9 < 1) {

Serial.println(" - leaning forward");

} else if (fsr0 < fsr2 && fsr0 < fsr3 && fsr1 < fsr2 && fsr1 < fsr3 && fsr0 > 0 && fsr1 >
0) {

Serial.println(" - sitting upright");

} else if (fsr0 > 0 && fsr1 > 0 && fsr2 < 1 && fsr3 < 1) {

Serial.println(" - slouching");

}else if (fsr0 > 0 && fsr1 > 0 && fsr2 < 1 && fsr3 < 1 && fsr4 < 1 && fsr5 < 1) {

Serial.println(" - slouching");

} else if (fsr0 > fsr1 && fsr2 > fsr3 && fsr0 > 0 && fsr1 > 0 && fsr9 < 1 && fsr10 < 1) {

Serial.println(" - leaning left");
```

```
} else if (fsr1 > fsr0 && fsr5 > fsr2 &&  fsr1 > 0 && fsr0 > 0 && fsr9 < 1 && fsr10 < 1)
{

Serial.println(" - leaning right");

} else if (fsr1 > fsr0 && fsr3 > fsr2 && fsr1 > 0 && fsr0 > 0 && fsr9 < 1 && fsr10 < 1) {

Serial.println(" - leaning right");

} else if (fsr0 < 1 && fsr1 > 0 && fsr2 > 0 && fsr3 > 0) {

Serial.println(" - left leg crossed");

} else if (fsr1 < 1 && fsr0 > 0 && fsr2 > 0 && fsr3 > 0) {

Serial.println(" - right leg crossed");

} else if (fsr0 < 1 && fsr1 > 0 && fsr2 > 0 && fsr3 > 0 && fsr10 > fsr8) {

Serial.println(" - left leg crossed, leaning right");

} else if (fsr1 < 1 && fsr0 > 0 && fsr2 > 0 && fsr3 > 0 && fsr8 > fsr10) {

Serial.println(" - right leg crossed, leaning left");

}else if (fsr1 < 1000 && fsr0 < 1000 && fsr2 < 1000 && fsr3 < 1000) {

Serial.println(" - none");

}

delay(1000);

}
```