AN INVESTIGATION ON TORSO MODEL FOR MONITORING COMPENSATORY MOVEMENT OF STROKE PATIENTS DURING CROSS-BODY REACHING

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in partial fulfillment of the requirements for the degree of
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DECLARATION

I declare that this thesis entitled "AN INVESTIGATION ON TORSO MODEL FOR MONITORING COMPENSATORY MOVEMENT OF STROKE PATIENTS DURING CROSS-BODY REACHING is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name :

Date :

APPROVAL

I hereby declare that I have checked this report entitled "AN INVESTIGATION ON TORSO MODELFOR MONITORING COMPENSATORY MOVEMENT OF STROKE PATIENTS DURING CROSS-BODY REACHING" and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Mechatronics Engineering with Honours

Signature : ....

Supervisor Name : ....

Date : ....

DEDICATIONS

To my beloved mother and father

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ABSTRACT

In this modern world civilization, stroke is known as one of the serious medical issue where almost nearly 800,000 people experience it each year. Due to brain damage, some stroke patients suffer the loss of motor function on the upper limb. Thus, compensatory movements are often utilized by stroke patients to adapt to the loss of motor function. To further improve the rehabilitation process, extensive monitoring on compensatory movements of stroke patients required to be done. Several researchers have come up with ideas on this topic despite that, some of the process may cause discomfort for example involving palpation process, and required experienced and skills, such as to accurately pinpoint the anatomical landmark. Thus, this project aims to identify comprehensive marker model for torso movement, to evaluate the differences between the proposed marker model with sternum displacement, and to assess the proposed marker model in evaluating cross-body reaching in simulated stroke. The proposed model is a belt model. However, the scope of this study has been limited to upper body monitoring only which involve in task and movement assessment on orientation and translation. Two subjects were identified and by utilizing motion capture, the torso movement for assigned task were recorded. The data from the trials were then analyzed. Thus, the cumulative sternum displacement and the stroke angle were evaluated. Normal and simulated stroke have almost identical trajectory pattern and only can differentiate by the z-axis coordinate. For the stroke angle evaluation, there is a consistency of the torso angles obtained during task for normal condition subject. However, we can see difference when normal and simulated-stroke data are compared. Significant differences can be observed in simulated stroke torso angles data as these subjects incorporate compensatory movement which affect the angle in lateral flexion, axial rotation and flexion. The findings will contribute to the researchers around the globe and to apply simpler marker model to monitor the movement of a stroke patients.

ABSTRAK

Dalam tamadun dunia moden ini, strok dikenali sebagai salah satu masalah perubatan yang serius di mana hampir hampir 800,000 orang mengalaminya setiap tahun. Kerana kerosakan pada otak, sesetengah pesakit strok mengalami kehilangan fungsi motor pada bahagian atas badan. Oleh itu, gerakan pampasan sering digunakan oleh pesakit strok untuk menyesuaikan diri dengan kehilangan fungsi motor. Untuk mempertingkatkan lagi proses pemulihan, pemantauan yang luas terhadap pergerakan pampasan pesakit strok perlu dilakukan. Beberapa penyelidik telah membuat idea-idea mengenai topik ini walaupun, beberapa proses boleh menyebabkan ketidakselesaan misalnya yang melibatkan proses palpasi, dan memerlukan pengalaman dan kemahiran, seperti yang tepat menentukan landasan anatomi. Oleh itu, projek ini bertujuan untuk mengenal pasti secara menyeluruh model penanda untuk pergerakan badan, untuk menilai perbezaan antara model yang dicadangkan dengan anjakan sternum, dan untuk menaksir model yang dicadangkan dalam menilai pergerakan silang badan dalam simulasi strok. Model yang dicadangkan adalah model tali pinggang. Namun begitu, skop kajian ini hanya terhad kepada pemantauan badan atas sahaja yang melibatkan penilaian tugas dan pergerakan pada orientasi dan terjemahan. Terdapat dua subjek telah dikenalpasti dan dengan menggunakan sistem penangkapan pergerakan, gerakan pada tubuh telah direkodkan. Maklumat daripada percubaan telah pun dianalisa. Oleh itu, kumulatif anjakan sternum dan sudut strok telah dinilai. Subjek normal dan strok disimulasikan mempunyai corak trajektori yang hampir mirip dan perbezaan dapat dilihat hanya pada koordinasi paksi-z. Untuk penilaian sudut strok, terdapat konsistensi pada sudut badan yang diperoleh ketika menjalankan tugas untuk subjek normal. Walaubagaimanapun, kita data melihat perbezaan ketika kita melakukan perbandingan antara normal dan simulasi strok. Perbezaan ketara dapat dilihat pada sudut simulasis strok kerana subjek menggabungkan gerakkan pampasan yang akan menjejaskan sudut pada lekapan lateral, putaran paksi dan flexion. Pencarian ini akan menyumbang kepada ahli penyelidik seluruh dunia dan untuk mengaplikasikan penggunaan marker model yang lebih mudah untuk memantau pergerakan pesakit strok.

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LIST OF SYMBOLS AND ABBREVIATIONS

D,d	-	Diameter
FYP	-	Final Year Project
M	-	Male
ISB	-	International Society of Biomechanics
STC	-	Standardization and Terminology Committee
STRN	-	Sternum

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Overview

Following is a section that briefly outlines the contents of an entire dissertation such as motivation, problem statement, objectives and scopes of study. It is based on motivation regarding the proposed project with existing problem in real life. Besides that, objectives of this project set aim to resolve the problem that are existing in our day-to-day life. Moreover, the scope of study incorporates the area study of experiments, target of the project and limitation.

1.2 Motivation

Stroke is the fifth-leading cause of death in the United States [1]. Approximately around 800,000 people have a stroke each year. That sums up to a total of one person every 40 seconds. A stroke occurs when blood supply to the brain is either decrease or interrupted. Stroke are categorized into two types: ischemic, due to absence of blood flow, and hemorrhagic, due to blood loss. It affects one part of the brain to not function effectively.

Nowadays, post stroke rehabilitation has been evolving significantly in the fields of robotics and game-based rehabilitation [2]. Researchers from all over the world have come up with experiment to observe the compensatory movement. However, the implementation of the experiment is not easy as it is meticulous and often required experience and skills. Along with the lack of professional guidance, expensive equipment is also one of the main factors that the experiment is impossible to be execute elsewhere.

Thus, a simpler marker model is proposed in this paper in order to assist interested parties and ease their job when it comes to assessing compensatory movement of stroke patients.

1.3 Problem Statement

The fact that to locate anatomical landmark, manual palpation is required. Palpation is a method of using one’s hands to check a person physical, especially while examining or diagnosing a sickness or disorder. Analysis of palpation make known that it combines two types of sensation: that of touch and of motion. The sense of touch is just as important in this process as the sense of sights. However, palpation may create certain levels of discomfort toward individuals. Thus, it is important for the examiner to establish good communication with patients during the process.

Next, to accurately pinpoint the anatomical landmark, the assistance of a professionals is required. Palpation is a highly specialized skill and may be considered to be one of the primary skills of a health care practitioner. Mastery of anatomy and much practice are required to attain a high level of skill. So, when the procedures are carried out by non-professional individual, it might not be accurate. Hence, the data obtain consists of unnecessary errors.

When carrying out the experiment, it is required to place marker on subjects’ body. However, marker placement will vary for each session. For example, subject A involve in day one of the experiment. Due to certain error, subject A are required to attend the experiment session again on day two. However, there is slight difference in the data obtained between both days. One of the logic reasons are due to the difference in position of marker placement between day one and day two. Even the slightest difference in marker placement on a same subject will produce different results. The variable will be the placement of the marker. Thus, repeatability is questionable.

1.4 Objectives

The goal of this project is: -

1. To identify comprehensive marker model for torso movement.

2. To evaluate the differences between the proposed marker model with sternum displacement.

3. To assess the proposed model in evaluating cross-body reaching in simulated stroke.

1.5 Scopes of study

The study of this project is mainly focus on upper body monitoring only. Lower body movement is assumed irrelevant to torso compensation in assessment task such as point-to-point drawing.

The task that will be carry out during this experiment will be cross-body reaching. Thus, the upper body which is involve in the model through the process of the task only are monitored.

The analysis is expected to focus on movement assessment that will be on orientational and translational.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter present details explanation on compensatory movements, torso definition, monitoring tools, assessment task and analysis of data. The mechanism and working principal are explained. Three different marker models that are used in this investigation are introduced. Review on previous works related to the investigation of torso model for monitoring compensatory movements are studied and presented in this chapter.

2.2 Identification of Compensatory Movement

Compensatory movement is regularly observed in stroke patients. It accompanies poor functional outcomes. People who suffer from stroke display slow, less efficient, less smooth and less precise trunks movements if being compare with a healthy individual [8]. The level of motor disability may be related to the application of compensatory movement. These motor deficits restrict voluntary, well-coordinated and effective movements of an affected person. Motor compensation in trunk includes the utilization of torso, scapular and also shoulder abduction and internal rotation [11]. It is to assist arm and hand transport to aid hand movement as methods for compensatory strategies [11]. In order to overcome the absence of distal voluntary and have better function and position, stroke patients usually will include the use of compensatory strategies to support arm transport [2]. A lot of post stroke patients have disable arm and hand function at the affected body side, thus constraining the independent performance of activities in everyday life [3]. Patients that are mildly impaired tended to perform healthy movement patterns, meanwhile patients that are severely to moderately impaired incorporate new degrees of freedom to compensate for motor deficiency [7]. As seen in Figure 2.1, for a healthy person, movement during reaching are normal. However, for post stroke person, they compensate movement of shoulder rotation and trunk forward, assisted movement and non-paretic limb can be observed during a reaching task.

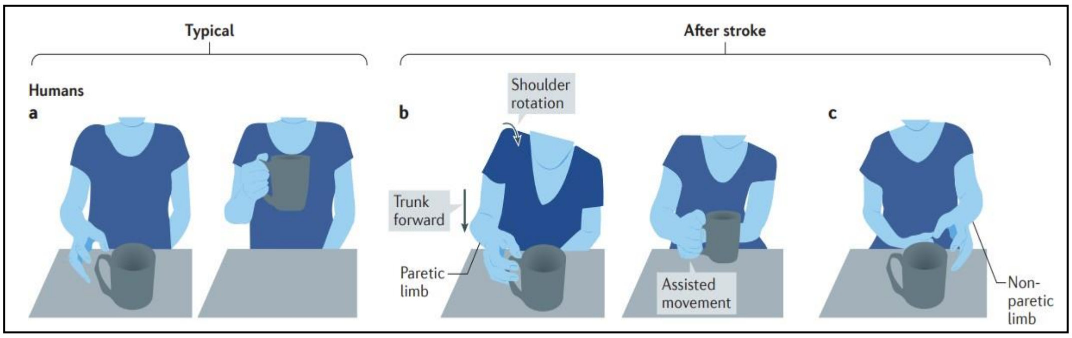


Figure 2.1 Difference in movement before and after stroke

2.3 Torso Definition

Torso is the anatomical term for the central part of many animal bodies which includes human. Human trunk is the essential part of the skeleton and take part in a vital role to maintain equilibrium control over whole body and making sure mobility during day to day activities. The body part that includes in torso are chest, abdomen and back. Torso movement can be categorized into 3 planes: forward bending can be seen as movement parallel to sagittal plane, axial rotation is parallel to transverse plane and lateral flexion is parallel to coronal plane as shown in Figure 2.2.

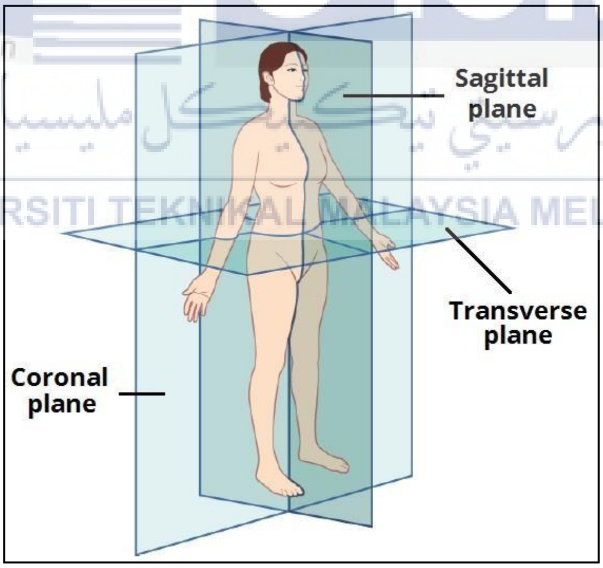


Figure 2.2 Anatomical plane

The human upper body has redundant degrees of freedom to perform a variety of tasks. Six Degrees of Freedom are provided by this system which three are active and three are passive which is roll, pitch and yaw rotations [5]. The torso angles are determined by the direction of the torso segment moved which respective to the global coordinate system [6].

Right side bending of torso is define in the positive direction and to the left is define as negative direction [6], as shown in Figure 2.3.

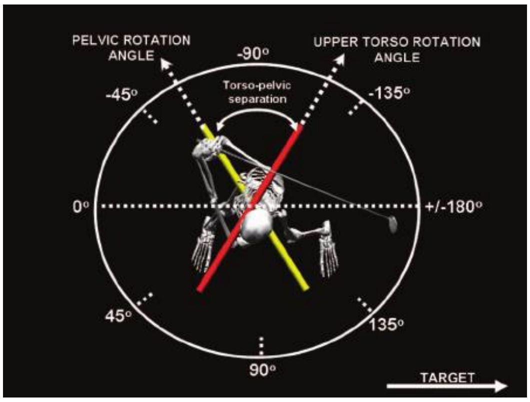


Figure 2.3 Upper torso rotation angle

2.4 Monitoring compensation using motion camera

Motion camera system are applied in countless of fields. The studies that incorporate motion capture system can be found in sport performance, animal science or biomechanical research. Some of the clinical science trials include gait analysis such as body movement and positioning. Vicon is one of the important systems when it comes to optoelectronic motion capture systems based on markers [12]. One of the most commonly applied Vicon model is the Plug-In-Gait model [13]. It is also named as the “Conventional Gait Model”, which is developed by Kadaba et al. [14,15], and Davis et al. [16]. The markers model recommended are from the Vicon Plug-In-Gait marker placement labelling configuration. It has 39 markers and each body segments are defining respectively; head, torso, arms, forearms, hands, upper legs, lower legs and feet as shown in Figure 2.3.

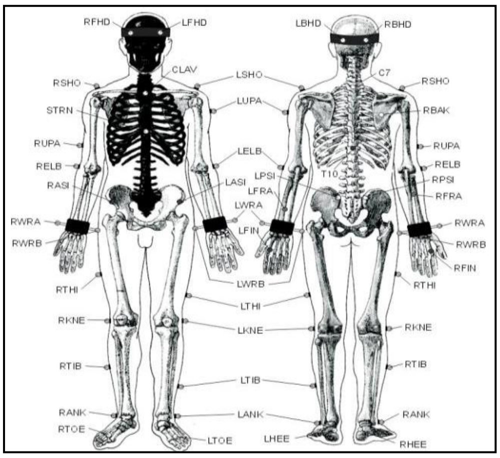


Figure 2.4 Plug-In-Gait marker model

Bortolami [17] research on the kinetic analysis of arm reaching movements during voluntary and passive rotation of the torso. The goal is to determine whether the arm movement accuracy is conserved by feedforward compensations for self-generated Coriolis forces when voluntary torso rotations is carried out. The conclusion is that there is preceding pre-programmed compensation for self-generated Coriolis forces throughout voluntary body part rotation contingent on intended torso motion and arm trajectory.

Diaz et al. [18] proposed evaluating accuracy of motion analysis systems. Several markers were placed on a frame. The frame was then spin by an electric motor. Different experiments were carried out by implementing two different distances between markers and applying two different rotational speeds. The difference in distance between marker was applied to determine the performance of the motion capture devices. The conclusions indicate that the if the tracked object are closer to the camera, the better the performance of the motion capture setup. Moreover, slow motion patterns provide better performances for the camera setup.

2.5 Assessment Task

When performing a task involving arm and forearm coordination, stroke patients will incorporate compensation in terms of torso movement [2]. Cross-body reaching is one of the clinical assessment tasks that expects a compensatory movement when performed with an impaired arm. Forward bending can be seen as movement parallel to sagittal plane, axial rotation is parallel to transverse plane and lateral flexion is parallel to coronal plane. The sitting position is standardized to the individual’s body size and the task is performed at a comfortable pace speed and compensatory movements are not constrained. This is to maintain the task natural and close to real-life situation to improve ecological validity of the protocol [22].

The movement pattern will be from initial position of either one left or right arm is bend and index finger touching ear lobe, then swing downward towards knee which is vice versa with the chosen hand as shown in Figure 2.4. The end effector will be the palm of the chosen arm. Data of the movement will be recorded using the Vicon motion capture camera and analyze.

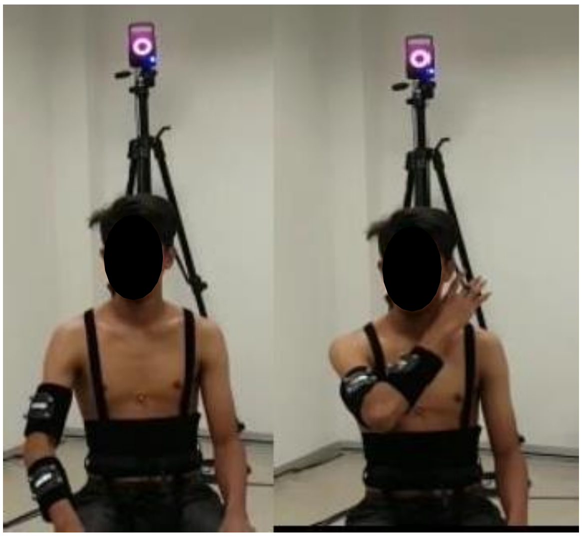


Figure 2.5 Cross-body reaching task

Assessment of stroke patient’s movement has been acceptable from robot-assisted rehabilitation studies to various types of assessment activities. One of the assessment tasks is reaching task based as it is a fundamental of activities involve in daily life [4]. Besides that, point-to-point drawing are usually also one of the tasks that were carried out during assessment. The difference between stroke patients and a healthy person are, stroke patients drawing produce a crooked line however a healthy person can draw a straight line, Figure 2.5.

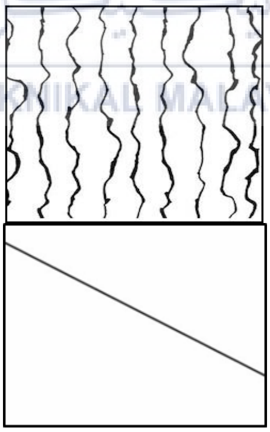


Figure 2.6 Crooked line and straight-line drawing

Besides that, Neo et al. [22] mentioned that the strokes will be classify by the system into three different categories which is simple straight line, arc and complex straight line. Example of simple straight lines are vertical, horizontal and oblique line. Combination of two or more straight lines written in one stroke such as L, V and Z are complex straight lines. Curve strokes contains curvature including circles and semicircles.

2.6 Sternum Displacement

Compensatory and normal movement both involve the trunk displacement or sternum displacement. Trunk or sternum displacement can be quantified as angular kinematics which characterizes movement patterns in terms of temporal and spatial joint and axial rotation, lateral bending and, flexion and extension [22]. The correlation between sternum and other body parts are significant. Whenever a movement involve upper body, the sternum moves along to compensate the motion. Individuals with stroke did lean forward (trunk displacement) while performing a task [22]. Sternum displacement can be seen from the maximum displacement of the sternum marker from the initial position during the entire drinking task.

2.7 Position and Orientation Determination

After the task assessment are done on subjects and data are collected, calculation on the position and orientation of the torso model needed to be done. The Standardization and Terminology Committee (STC) of the International Society of Biomechanics (ISB) has proposed one set of standards to define joint coordinate systems of various joints [19].

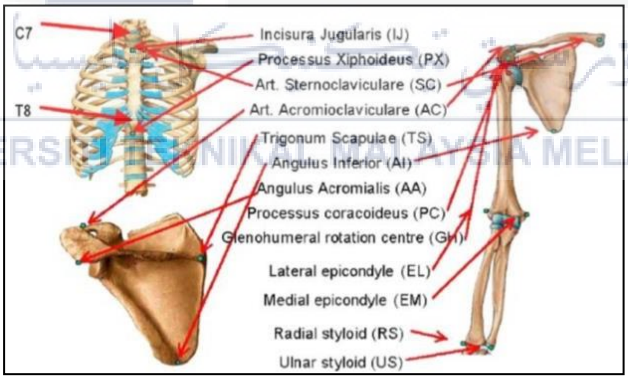


Figure 2.7 Torso model

By referring to ISB model [19], the thorax coordinate system is labelled as below Figure 2.6,

- O_t is the starting point correspondent with IJ.
- Y_t is the line connecting midpoint among PX and T8, and the midpoint among IJ AND C7, pointing upward.

- Z_t is the line perpendicular to the plane form by IJ, C7 and the midpoint between PX an T8, indicating to the right.

- X_t is the common line perpendicular to the Z_t and Y_t axis, pointing forward.

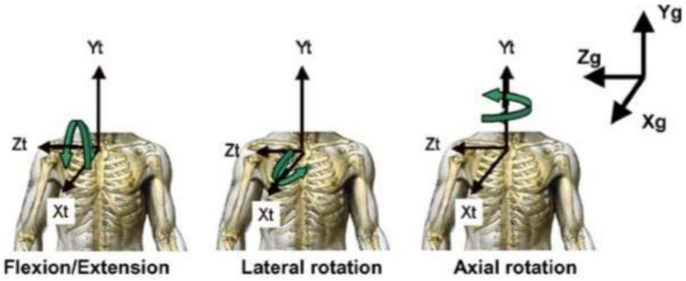


Figure 2.8 Thorax coordinate system

For Vicon Plug-In-Gait model, the upper body position and orientation are different from the ISB proposed model. Marker are labelled as,

• C7 is the 7th cervical vertebra.

• T10 is the 10th thoracic vertebra.

• CLAV is the clavicle.

• STRN is the sternum.

• RBAK is the right back.

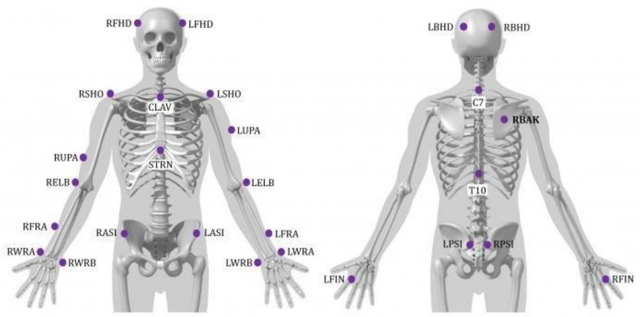


Figure 2.9 Vicon upper body coordinate system

The global Z axis defines the vertical, i.e. perpendicular to the floor as shown in Figure 2.8. The global X and Y axes are in the plane same as the floor, with X often defined as the direction of normal walking along a pathway.

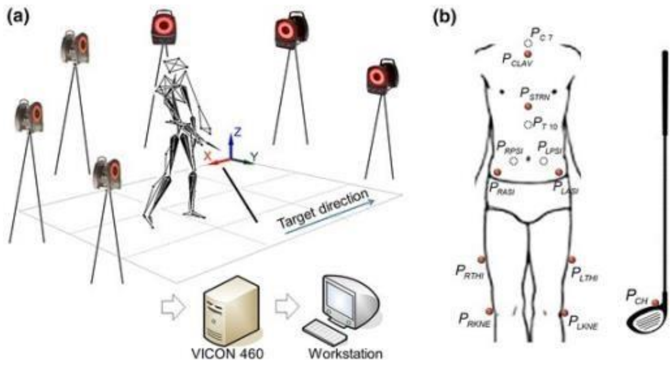


Figure 2.10 Global axes for Vicon coordinate system

The B&L engineering proposed belt model are different from the previous models. For this particular model, we can assume the origin at any marker on the belt model as in Figure 2.8. For the B&L Engineering marker clusters model, the model marker is label top right (origin axis), bottom right (primary axis), top left (secondary axis) and bottom left (additional axis).

Figure 2.11 B&L Engineering belt model

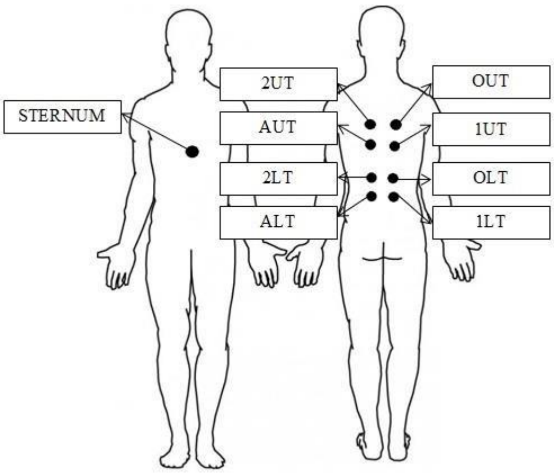


Figure 2.12 Labelling in Vicon Nexus software

From the figure above, apply the cross product between vector of Y-axis and Z-axis to find the Z-axis for upper torso and lower torso. X1- X2 is to find the Y-axis while X1-X3 is to find the Z-axis. As a result, the axis for upper torso and lower torso were determined. Proximal is refer to lower torso while the distal refer to upper torso.

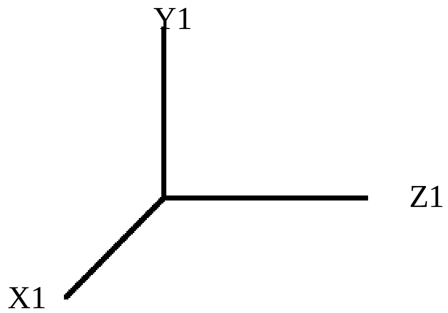


Figure 2.13 Coordinate system

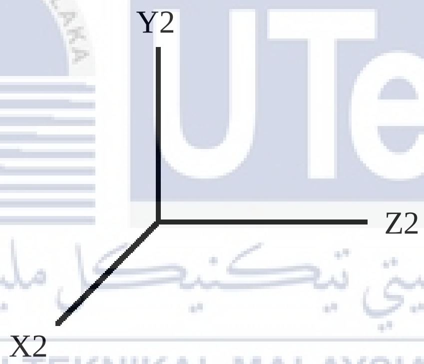


Figure 2.14 Coordinate system

The formula below is applied to determine the unit vector based on the coordinate system in Figure 2.12 and Figure 2.13.

$$\vec{V} = \frac{V}{|v|} \tag{2.1}$$

And $|v| = [X_3Y_3Z_3\ X_1Y_1Z_1\ X_2Y_2Z_2\ X_4Y_4Z_4]$ (2.2)

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter will propose the methodology of this project. Details procedures of camera setup and calibration, and the analysis of torso model to identify the comprehensive marker model for torso movement, evaluate the differences between the proposed marker model with sternum displacement and assess the proposed model in evaluating cross-body reaching in simulated stroke. The sequence of the methodology will first be the setup of workspace and followed by the calibration software and hardware which is Vicon Nexus and Vicon motion capture camera, then the collection and analysis of the data obtained.

3.2 Project Methodology Flow Chart

Figure 3.1 shows a brief process on how the experiment will be conducted.

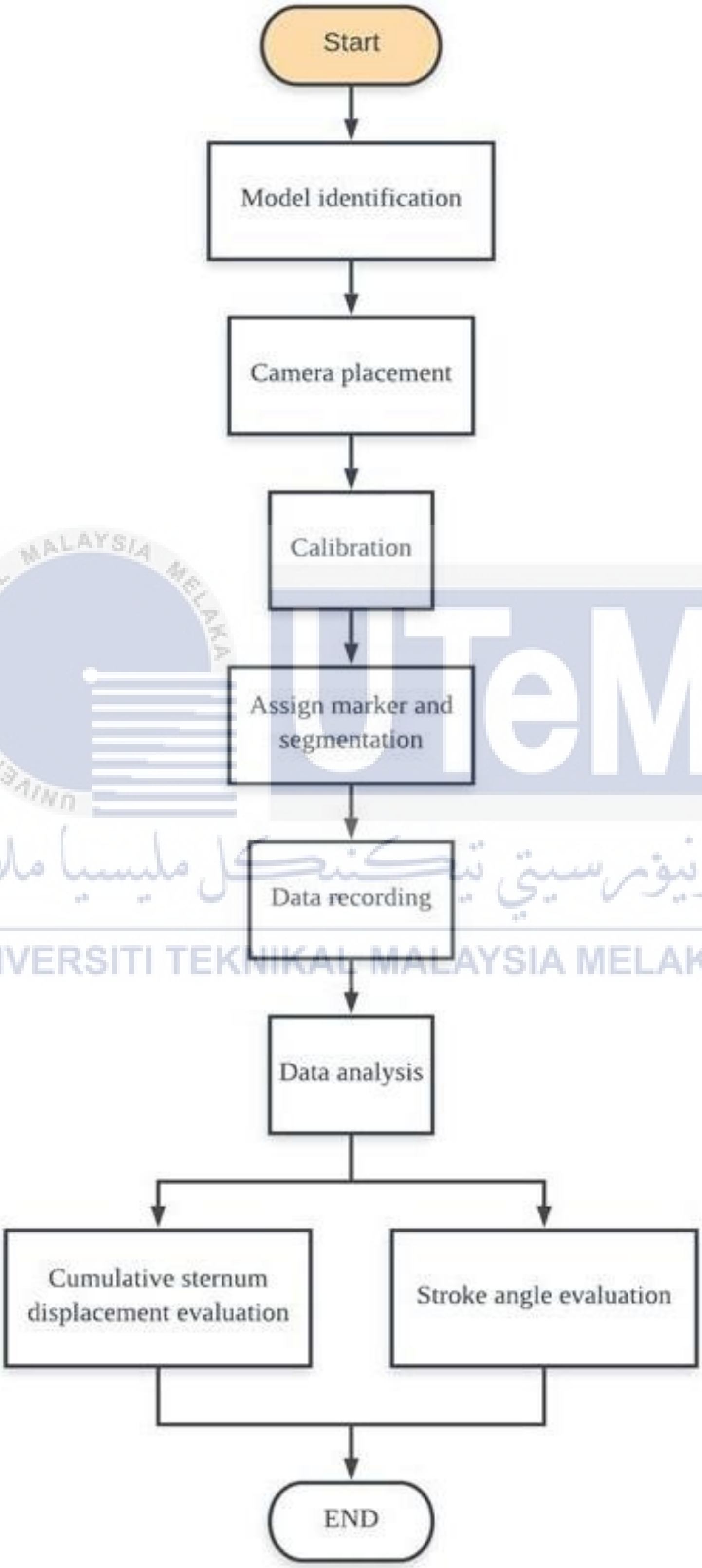


Figure 3.1 Project methodology flow chart

3.3 Protocols

The kinematic data was measured from four different subjects age 23 and 24 years old and their movement was captured as they performed the task by using Vicon motion capture cameras. Subjects were divided into two groups; Group 1 was for healthy subjects and Group 2 was for simulated stroke subjects. Subjects were placed with the B&L Engineering marker cluster belt for upper torso and lower torso, and an attachable retroreflective marker on the sternum and fingers. The subject demography data can be referred in Table 3.1.

Table 3.1 Demography data for the subjects

Subject	**Age**	**Sex**	**Condition**
001	23	M	Group 1: Normal
002	24	M	Group 1: Normal
003	23	M	Group 2: Simulated stroke
004	24	M	Group 2: Simulated stroke

Subjects were asked to perform a task which is cross-body reaching task while seated in a chair without back support and wheels. The trunk will be stabilized by sitting straight and correct posture. The shoulder was in approximately 0° flexion and extension 0° of internal rotation and elbow is in 75° to 90°, flexion with the wrist rested palm down and the finger joints in slight flexion positioned on the knees.

The beginning, reaching and ending position part of the task are determined through the velocity measurement reading. The initial velocity at the starting position is $0ms^{-1}$ increasing at the beginning, the reaching was determined when the velocity decreased to $0ms^{-1}$, and ending at completely $0ms^{-1}$ velocity measurement reading which indicated stop motion.

Table 3.2 Phase movement definition

Phase	**Activity**	**Detect by**
Rest position	Hand position is horizontal with the subject	Velocity value is zero
Move cross-body	Hand begin to move towards the targeted area	Velocity value positively increased
Reaching target	Hand almost reach the targeted area	Velocity value slowly decreased
Reach target and stop	Hand position is horizontal with subject, reach targeted area and fully stop	Velocity value will be at zero

Some modifications needed to be done such as increased shoulder rotation on the starting position were allowed for the subjects to minimize any positional discomfort. Subjects were then be instructed to reach the end position and touched the ear lobe at 90% elbow flexion.

Subjects were given few practice trials prior to familiarize themselves with the task pattern and instruction, respectively for normal and simulated stroke. Up to ten trials of task movement were recorded, but only a limited amount of reliable data will be taken and analyze. Data collection was limited to ten trials due to the reason the subjects may feel the fatigue and to prevents the subjects from having stress issue when performed. Simulated stroke may cause more strained towards the subjects as the elbow braces, as shown in Figure 3.2 may cause a certain level of discomforts.

Figure 3.2 Elbow brace for simulated stroke

3.4 Workspace Setup

Equipment:

- Vicon Motion Capture camera
- A chair
- A table

Procedure:

1. Firstly, all three cameras are labelled accordingly as camera 1, camera 2 and camera 3.
2. All three cameras are set to approximately to the same height.
3. The angle of view of all the cameras are set to 45°.
4. The position of the cameras is set in a triangle formation as shown in Figure3.2. Camera 1 and 2 viewpoints will be facing each other. Meanwhile, camera 3 viewpoint will be perpendicular to camera 1 and 2.
5. A chair and a table are placed in the centre of all the cameras for the subject to execute the task given during experimental session.
6. Finally, calibrate the camera by using Vicon Nexus.
7. If the data obtain from the camera calibration process exceed the margin error, step 2 to step 6 will be repeated to achieve the optimum camera calibration position.

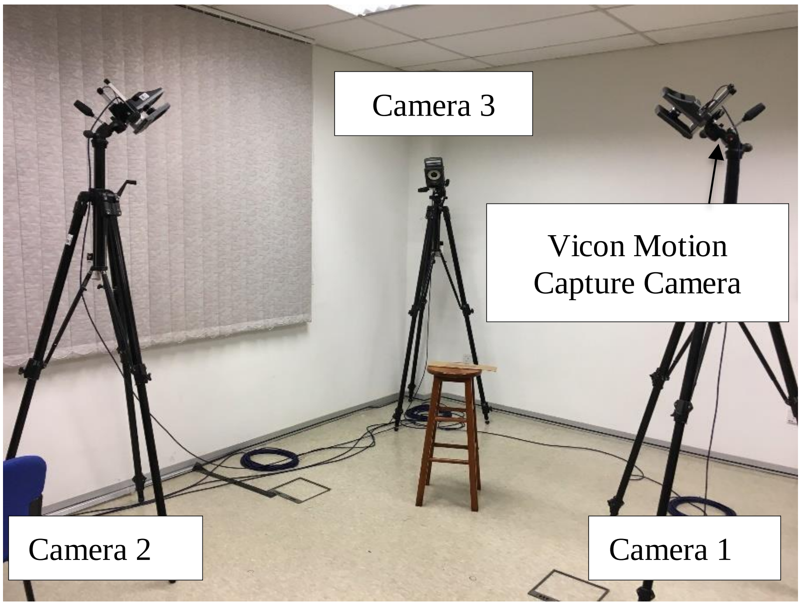


Figure 3.3 Workspace setup

3.5 Camera Calibration

Equipment:

- Vicon Motion Capture camera
- PC contain Vicon Nexus software
- Vicon Active Wand

Procedure:

1. First, switch ON the cameras.
2. Then, switch ON pc and access into Vicon Nexus software, Figure 3.3.
3. Switch Vicon Nexus into Live mode. Check if all cameras indicator is green which mean cameras are in standby mode as shown in Figure 3.4.
4. Next, wand set to active wand refer Figure 3.5.
5. Activate the calibration configuration.

6. Under calibrate cameras section, calibration type switch to full calibration and camera to calibrate select all cameras, refers Figure 3.5.

7. After that, click on START to begin camera calibration process.

8. During the calibration, Vicon active wand, Figure 3.6, will be used and make sure good number of wand frames are spread across the intended 3D capture volume as shown in Figure 3.7.

9. In the camera calibration feedback section, monitor the progress bar until the camera calibration process is complete.

10. Finally, the wand count and image error data are obtained, Figure 3.8.

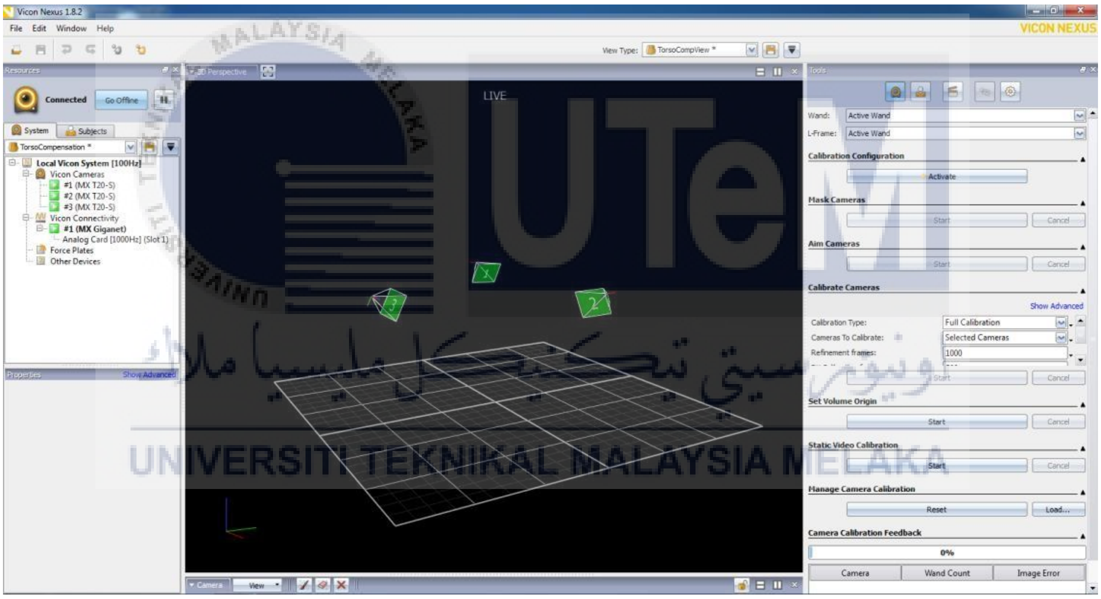


Figure 3.4 Vicon Nexus software

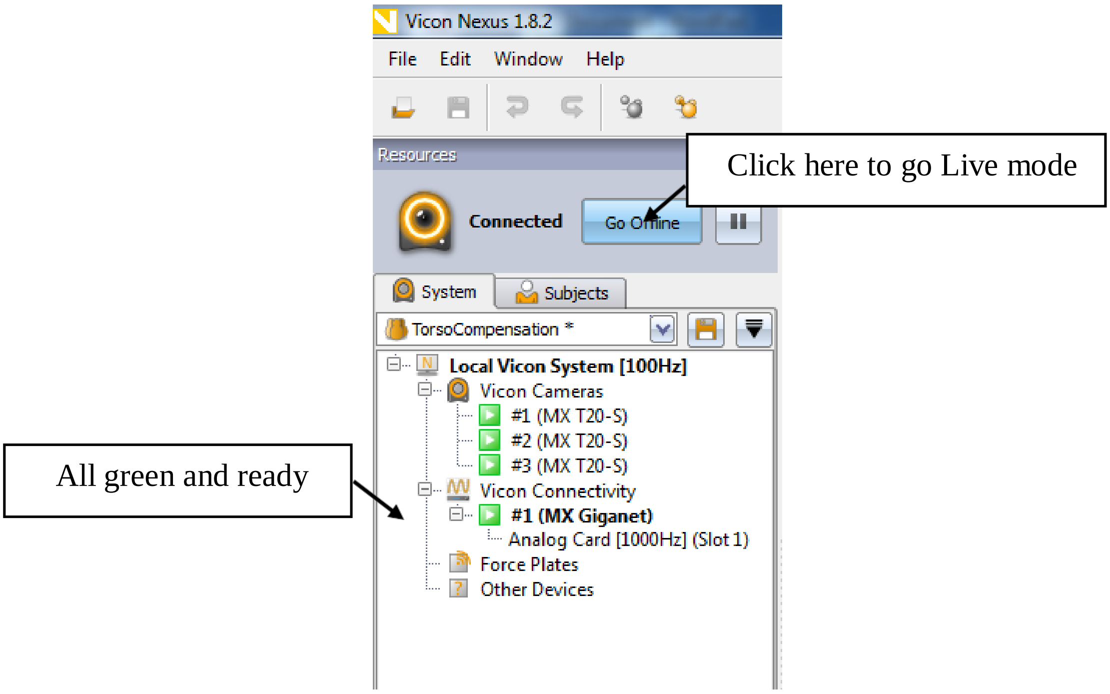


Figure 3.5 Live mode

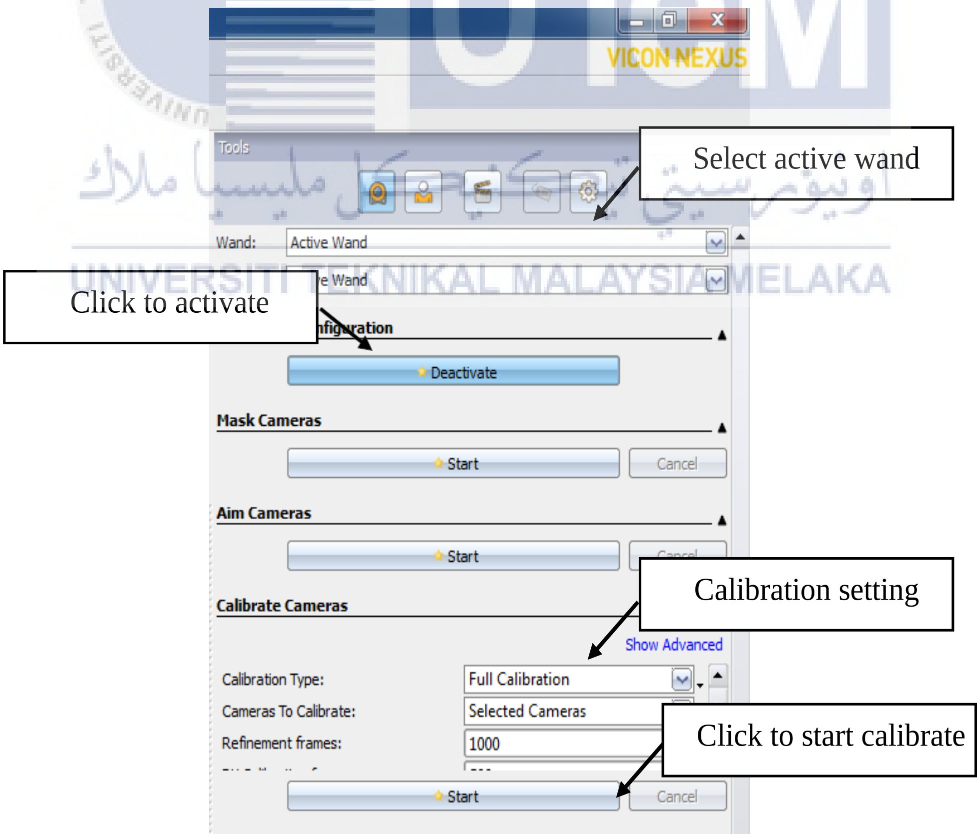


Figure 3.6 Preliinary setup before camera calibration

Figure 3.7 Vicon Active Wand

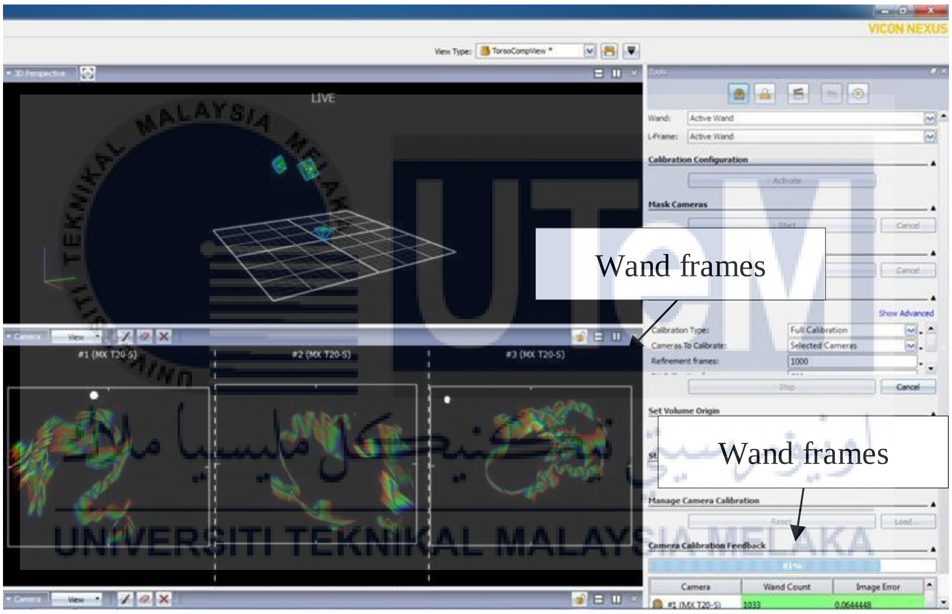


Figure 3.8 Calibration process involving active wand

Camera Calibration Feedback

0%

Camera	Wand Count	Image Error
#1 (MX T20-S)	1437	0.0716261
#2 (MX T20-S)	1002	0.0942687
#3 (MX T20-S)	2168	0.0834121

Figure 3.9 Wand count and image error data

3.6 Origin Setup

After the camera calibration process, the camera position in Vicon Nexus are not sets to the global origin and axes as shown in Figure 3.9. Thus, it is important to execute the volume origin setup.

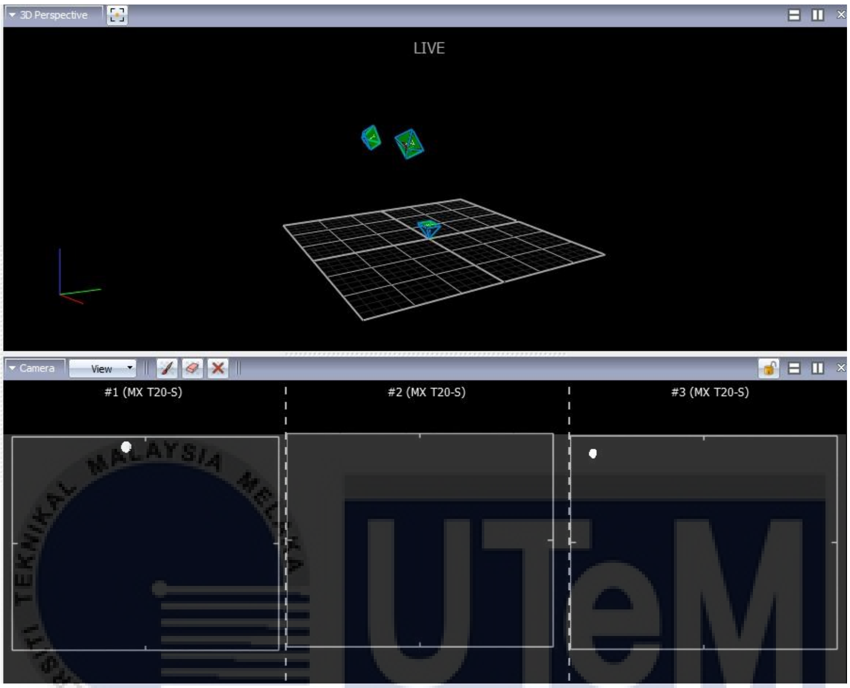


Figure 3.10 Camera unalign with global origin and axes

Equipment:

- Vicon Motion Capture camera
- PC contain Vicon Nexus software
- Vicon Active Wand

Procedure:

1. First, the active wand is place parallel on the ground in the centre of all three cameras as shown in Figure 3.10.

2. The active wand feet will be adjusted so that it is parallel to the surface.

3. Then, click on the set volume origin button, Figure 3.11.

4. Nexus sets the global origin and axes to correlate to the position and orientation of the calibration object in the capture volume as shown in Figure 3.11.

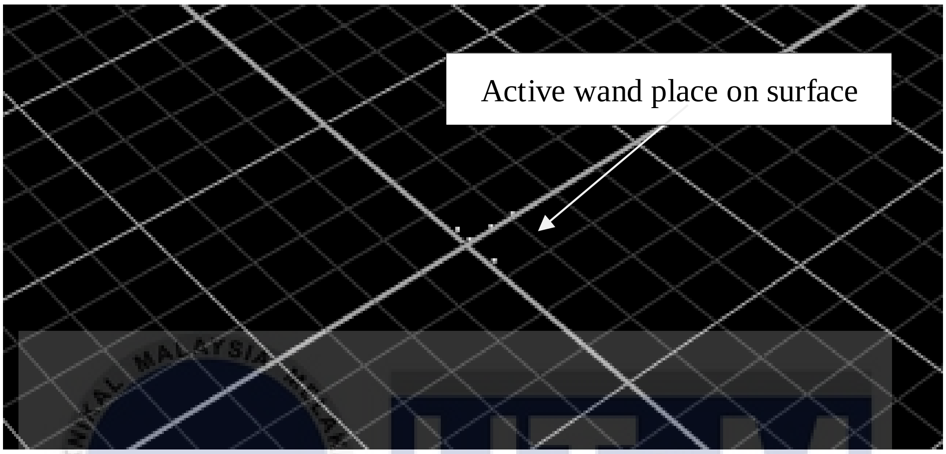


Figure 3.11 Active wand placed on ground surface

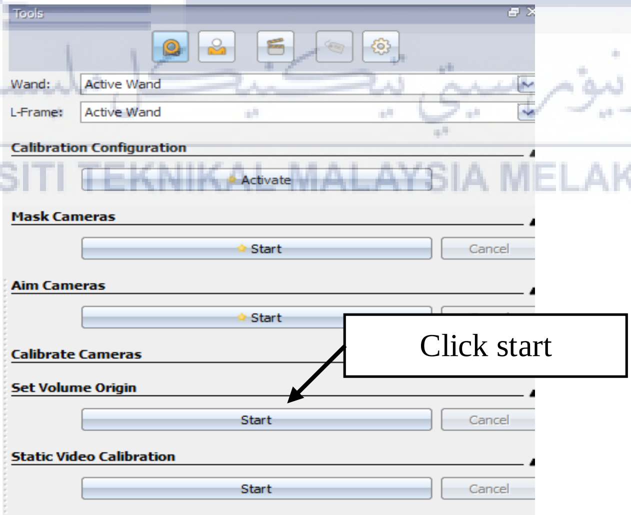


Figure 3.12 Set volume origin

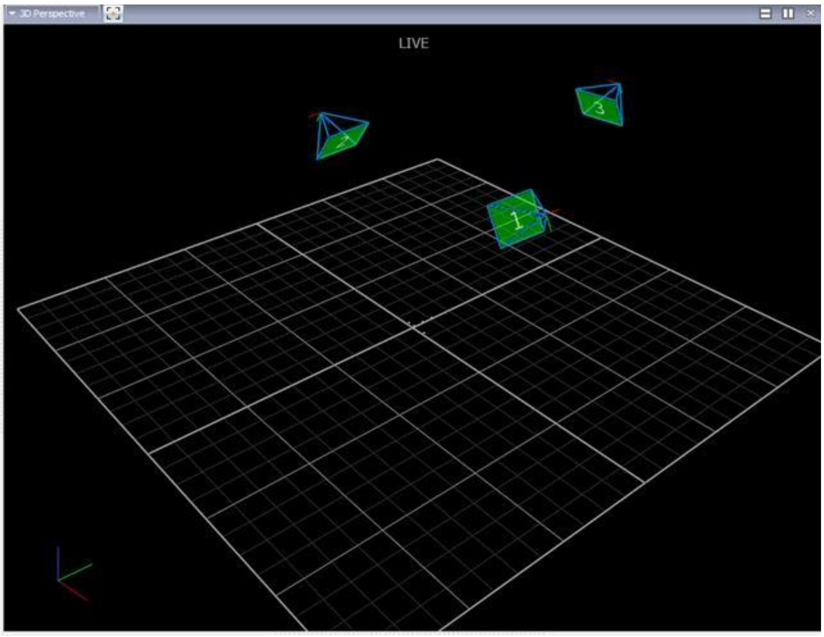


Figure 3.13 All cameras set to global origin and axes

3.7 Retroreflective Marker Placement

Equipment:

- B&L Engineering marker cluster – Upper and Lower Back
- B&L Engineering marker cluster – Arms
- Retroreflective marker

Procedure:

1. First, the lower back marker cluster will be strap on as shown in Figure 3.14.
2. Next, the upper back marker cluster will be strap on as shown in Figure 3.14.
3. Make sure that the marker cluster is strap on properly without causing any discomfort on the subject.
4. Then, one retroreflective marker, Figure 3.16, will be placed at the sternum.

5. Steps 1 to 4 will be repeated on other subjects.

Figure 3.14 Front view marker placement

Figure 3.15 Marker placement for upper and lower back

Figure 3.16 Marker placement for arm

Figure 3.17 Retroreflective marker

3.8 Motion Capture of Assessment Task

Equipment:

- Vicon Nexus software
- Vicon motion capture camera
- A chair
- A table

- Elbow brace

Procedure:

1. First, launch the Vicon Nexus software.

2. Then, press the button F2 to open the data management menu, as in Figure 3.17.

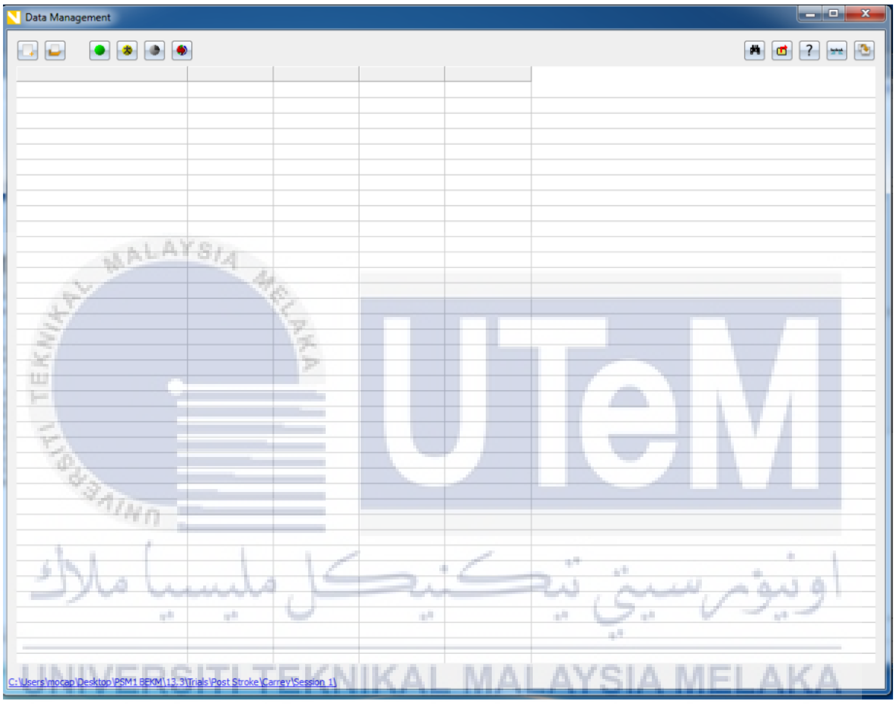


Figure 3.18 Data management menu

3. Begin with a new database. Set the desired location to store the data, name and description. Create the database in a format of "Clinical template.eni", as shown in Figure 3.18.

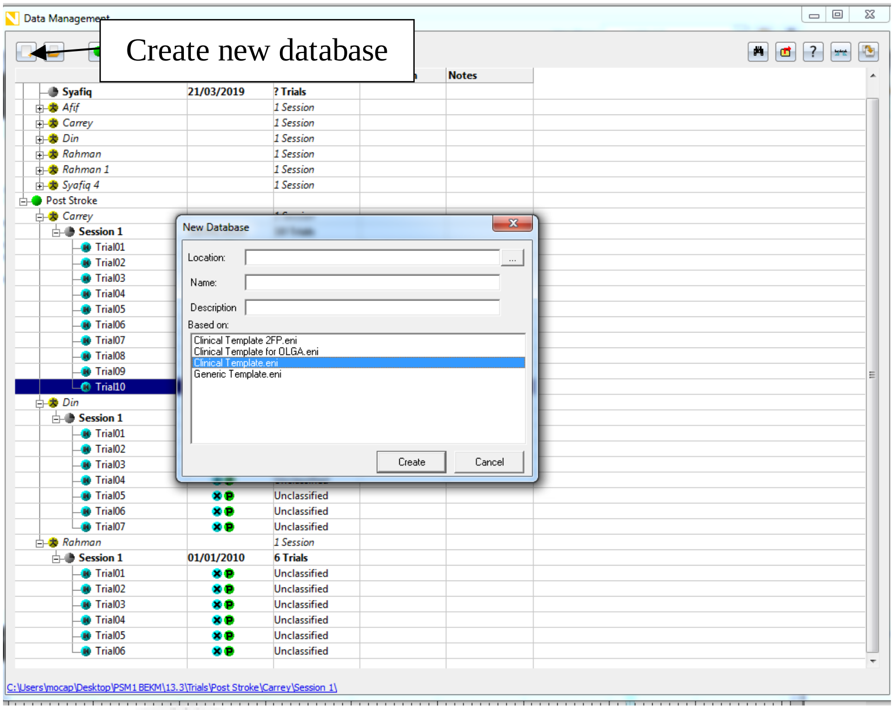


Figure 3.19 Create new database

4. After creating a new database, now create a new patient classification, as shown in Figure 3.19. Each of the new patient can be labelled according to the experiment conducted, so does new trials and session will be according to the number of experiments that have been carried out.

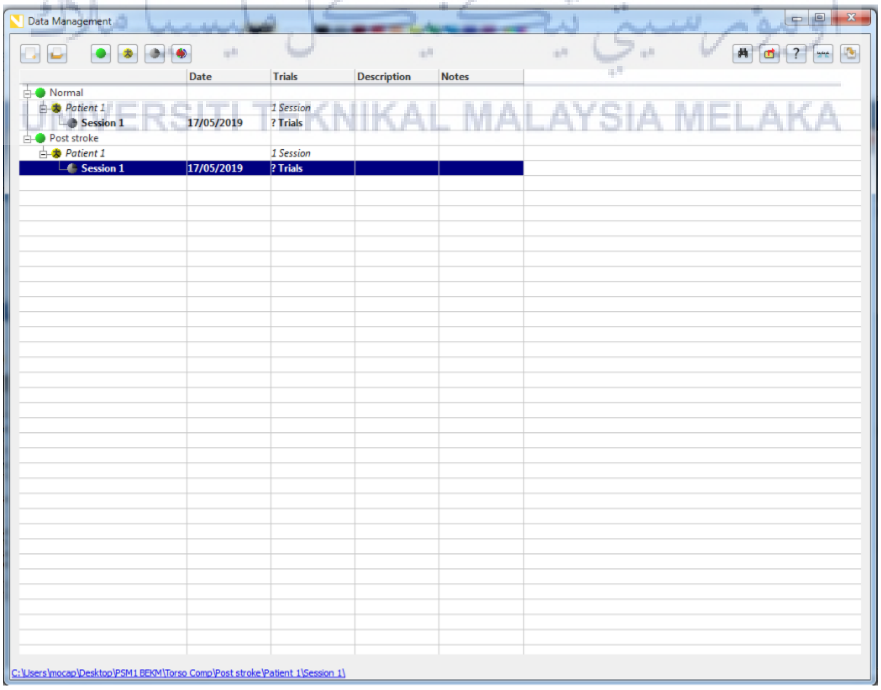


Figure 3.20 Create new patient classification

5. Close the data management menu. Proceed to Vicon Nexus interface, then create a new subject, as shown in Figure 3.20.

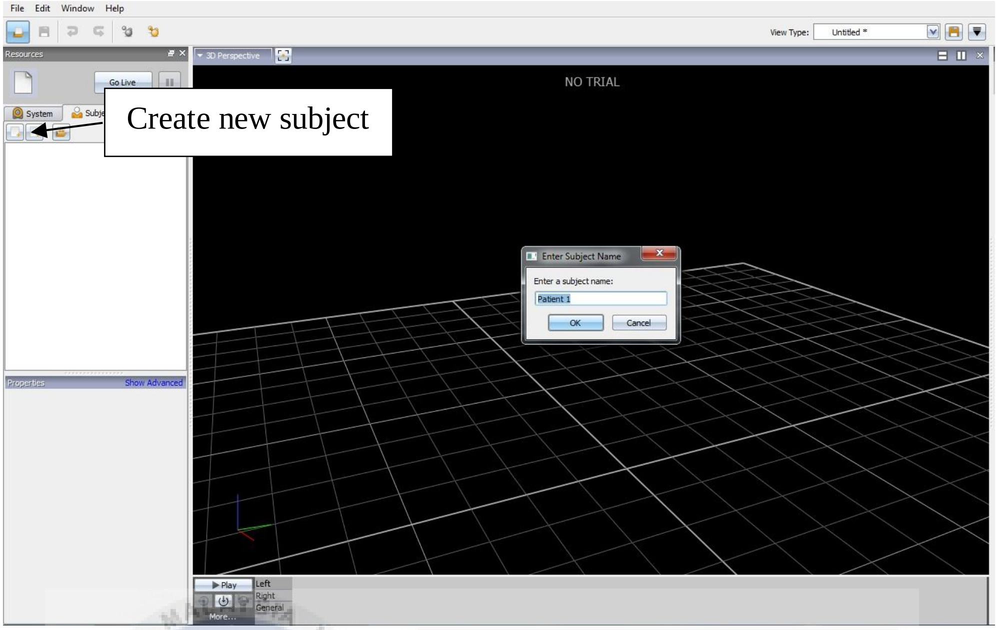


Figure 3.21 Create a new subject

6. After a new subject is created, in the Resources pane, click “Go live” shown in Figure 3.21. It is to enable the capture function.

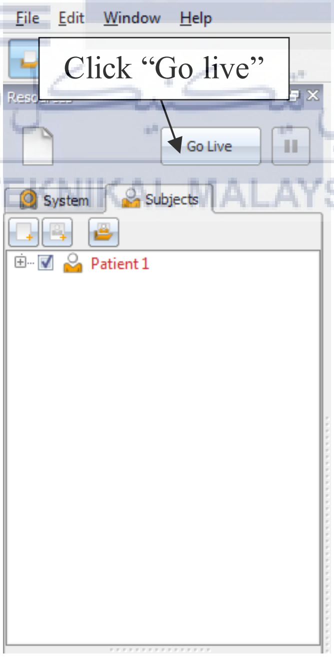


Figure 3.22 Press “Go live” to enable capture function

7. Proceed with capture session after making sure subject is well prepared. Click capture, and stop after each task, shown in Figure 3.22. Check each session

thoroughly by accessing the data management menu to make sure data recorded. This step is repeat for several time for more trials depends on the experiment.

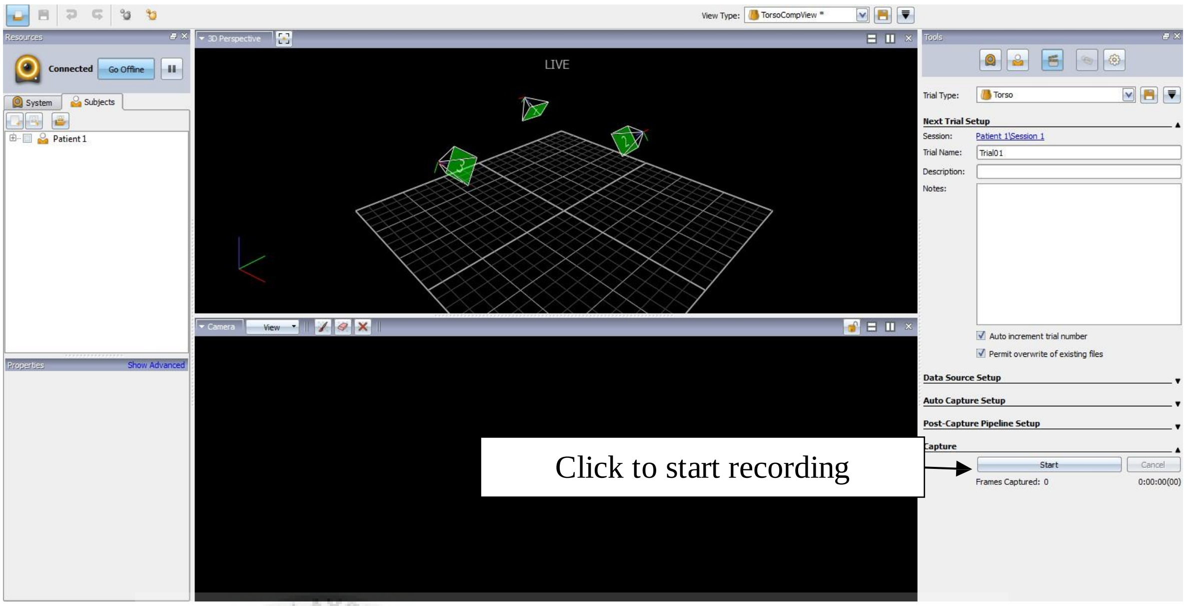


Figure 3.23 Motion capture session

8. From the data management window, open the desired trial file containing the raw trial data of that subject. From the Nexus toolbar, click "Reconstruct" button, refer Figure 3.24, to reconstruct the trial.

9. Create segment for different body parts. Under each segment, different anatomical landmark will be added as a marker respectively.

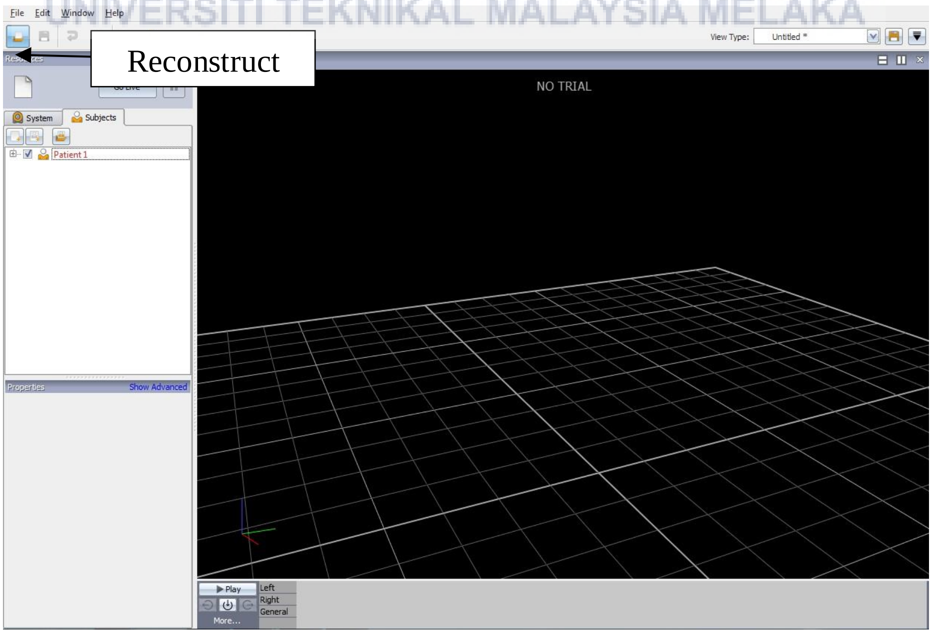


Figure 3.24 Reconstruct the trial

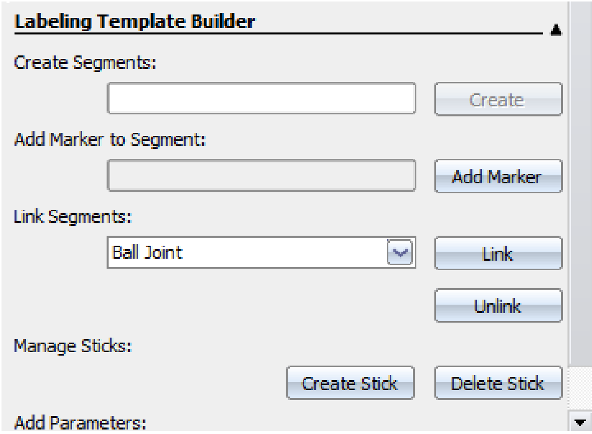


Figure 3.25 Segmentation and labelling

10. Manually label reconstructed trial data, as shown in Figure 3.25, for the selected subject in the Manual Labelling section of the Label/Edit tools pane.

11. Identify and fill gaps in reconstructed marker trajectories in the Gap Filling section of the Label/Edit tools pane.

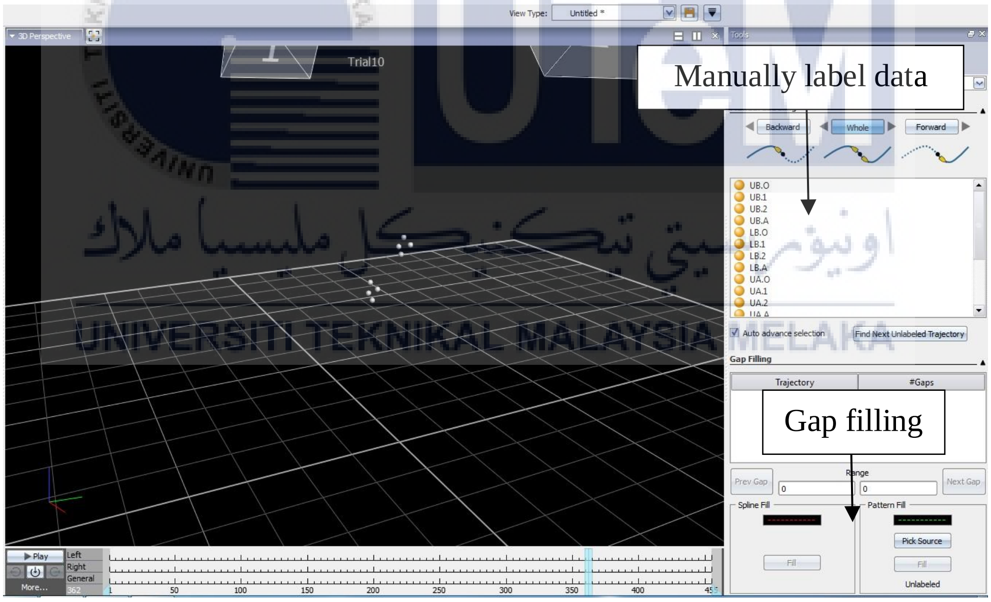


Figure 3.26 Manually label reconstructed trial data and gap fill

12. After labelling and gap filling, under the Pipeline Tools Pane, select “Export data to ASCII file” to obtain data in .csv format. Set the Frame Range setting from First Frame to End Frame, as shown in Figure 3.26.

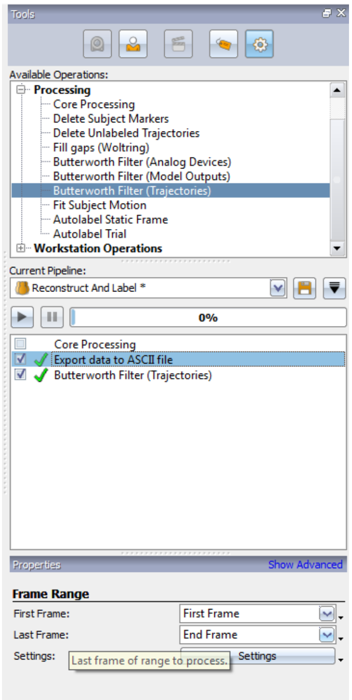


Figure 3.27 Set operation to export data to ASCII format

13. Next, select "Butterworth Filter (Trajectories)" to filter out signal noise above 6 Hz using a Fourth Order filter with zero lag and the frame range setting set from First Frame to End Frame, refer Figure 3.27.

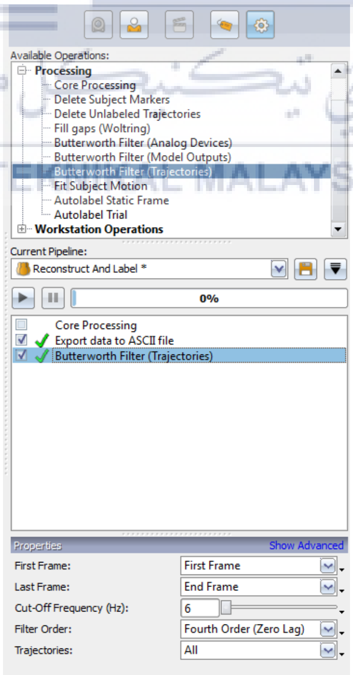


Figure 3.28 Set operation for Butterworth Filter

14. Click the “Run Pipeline” button, as shown in Figure 3.28, to start the pipeline process. Each operation is run in the order it appears in the list from top to bottom.

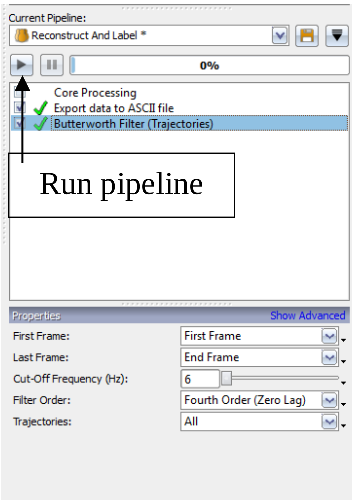


Figure 3.29 Start the pipeline process

15. Repeat step 8 to 14 for each raw trial data to obtain the data in .csv format for further analysis.

16. Elbow brace will be equipped on the subject to simulate stroke movement pattern. Trial data for simulated stroke will be taken same as the steps above.

3.9 Data analysis

The trials data were recorded and was transfer from data folder directly into Matlab by clicking File, Export and Directly into Matlab. Use Matlab command at the command prompt: (>> workspace) to navigate through the sets of Matlab variables.

3.9.1 Cumulative sternum displacement evaluation

The movement of the sternum is interpreted as the cumulative sternum displacement where every movement of the sternum, no matter if it is forward or backward, the movement is considered as a positive displacement.

$$Cumulative\ sternum\ displacement = \sum x1 + x2 + x3 + \cdots + xn \quad (3.1)$$

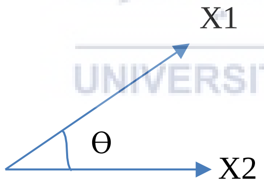
3.9.2 Stroke angle evaluation

The unit vector formula as per below:

$$\vec{v} = \frac{V}{|v|} \quad (3.2)$$

And $|v| = [X_3Y_3Z_3\ X_1Y_1Z_1\ X_2Y_2Z_2\ X_4Y_4Z_4]$ (3.3)

To find the angle between the two axes, apply the formula:



$$X_1.X_2 = X_1X_2\cos\emptyset \quad (3.4)$$

$$\emptyset = \cos^{-1}\left(\frac{X_1.X_2}{X_1X_2}\right) \quad (3.5)$$

From the axis that find at above, the rotation matrix is calculated by using formula as per below

$$[R]^T = \begin{bmatrix} i.I & j.I & k.I \\ i.J & j.J & k.J \\ i.K & j.K & k.K \end{bmatrix} \quad (3.6)$$

Lateral flexion angle, $\beta = \cos^{-1}(R_{1,3})$ (3.7)

Axial rotation angle, $\alpha = \tan^{-1}(\frac{R_{0,2}}{R_{2,2}})$ (3.8)

Flexion rotation angle, $\gamma = \tan^{-1}(\frac{R_{1,1}}{R_{1,0}})$ (3.9)

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Overview

This chapter presents the data obtained through the experiments that have been conducted. The workspace is fully prepared, and camera have been calibrated to the desired settings.

4.2 Workspace Setup

Figure 4.1 shows the final setup of the workspace that will be used to carry out experiment for this project. The cameras are positioned in a triangle formation. Reason being is so that at least two cameras are able to detect a marker which is located on subject body. Then a chair and a table will be placed in the centre of the cameras setup. The function of the chair and table are for the subjects to carry out the assessment task given. Next is to proceed with the experiment together with the test subjects.

Figure 4.1 Workspace setup completed.

4.3 Camera Calibration

The data for wand count and image error is obtained. The best value for image error is 0.05 and below. However, after the calibration has been done, the image error that was obtained can be seen in Figure 4.2. Despite the image error obtained is higher than the optimum value for image error, it is still acceptable as the limitations of the setup that is unavoidable.

Camera	Wand Count	Image Error
#1 (MX T20-S)	1033	0.0728018
#2 (MX T20-S)	1002	0.088177

Camera	Wand Count	Image Error
#1 (MX T20-S)	1033	0.0728018
#2 (MX T20-S)	1002	0.088177

Figure 4.2 Wand count and image error.

4.4 Hand tracing

The movement traveling of the hand tracing pattern were plotted from X, Y and Z axis. The analysis was to compare the pattern between the normal and simulated stroke side. From Group 1 hand tracing pattern, the reaching movement trajectory was smooth and more minimize. For simulated stroke, Group 2 data showed tracing travelled produced the similar pattern as the subject are still capable to carried out the cross-body reaching task but involving more compensatory movement. The difference between the hand tracing pattern of both groups are the reaching, as the normal subject can easily carried out the task while the simulated stroke subject has difficulties in carrying out the task as they will put on elbow brace to simulate the stroke patients situation. Through observation, there is a difference in the z-axis coordinate of the trajectory movement when compared normal and simulated stroke. The involvement of compensatory movement affects the trajectory movement in direction of z-axis.

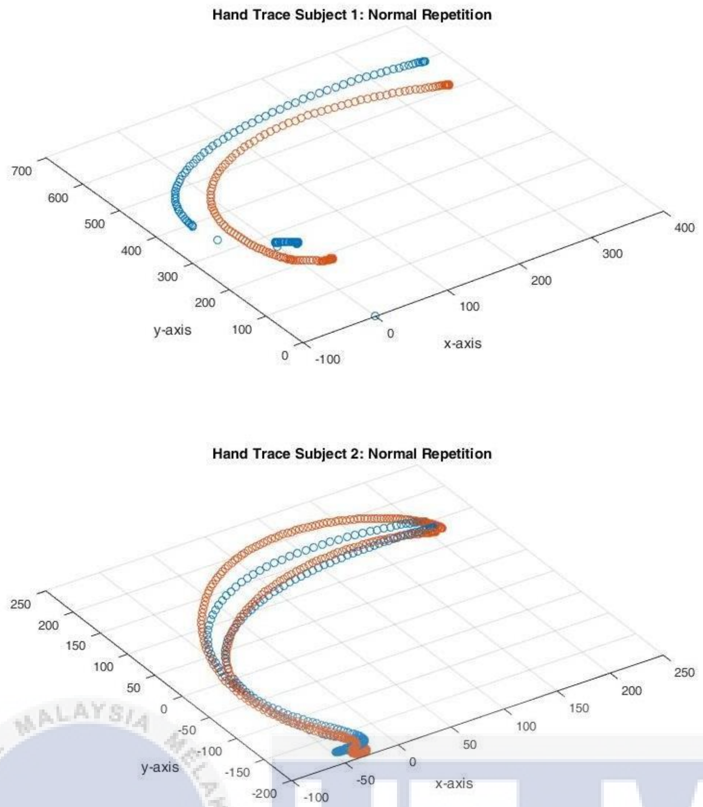


Figure 4.3 Hand trace for normal subject

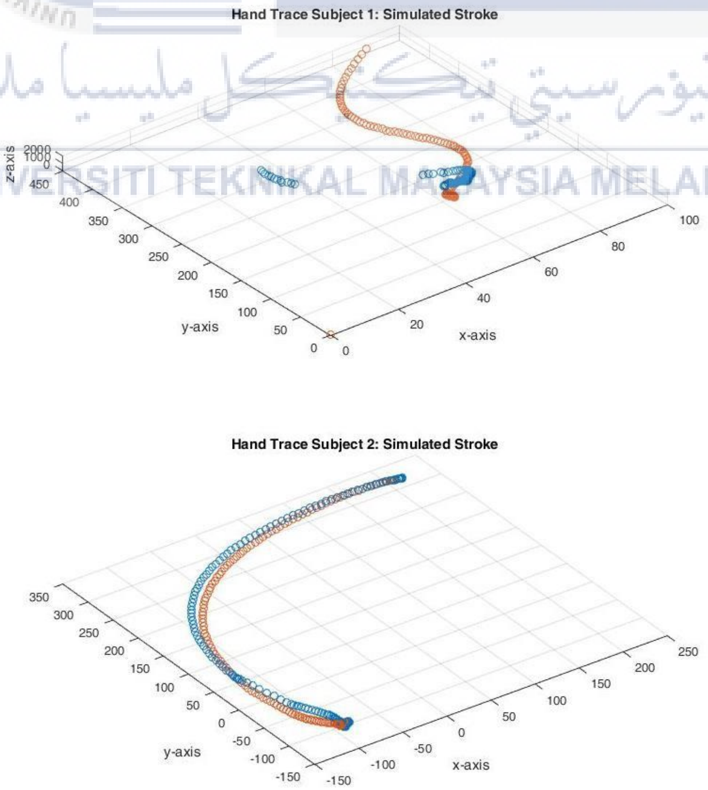


Figure 4.4 Hand trace for simulated stroke subject

4.5 Cumulative sternum displacement evaluation

The kinematics variables being analyzed through the reaching task evaluation is the displacement shown in Figure 4.5. The graph color indicates the different subjects and their repetition which is blue (subject 1 first repetition), orange (subject 1 second repetition), yellow (subject 2 first repetition) and purple (subject 2 second repetition). The displacement difference between the subjects varies as the data are also affected by the physical characteristics, for example the heights.

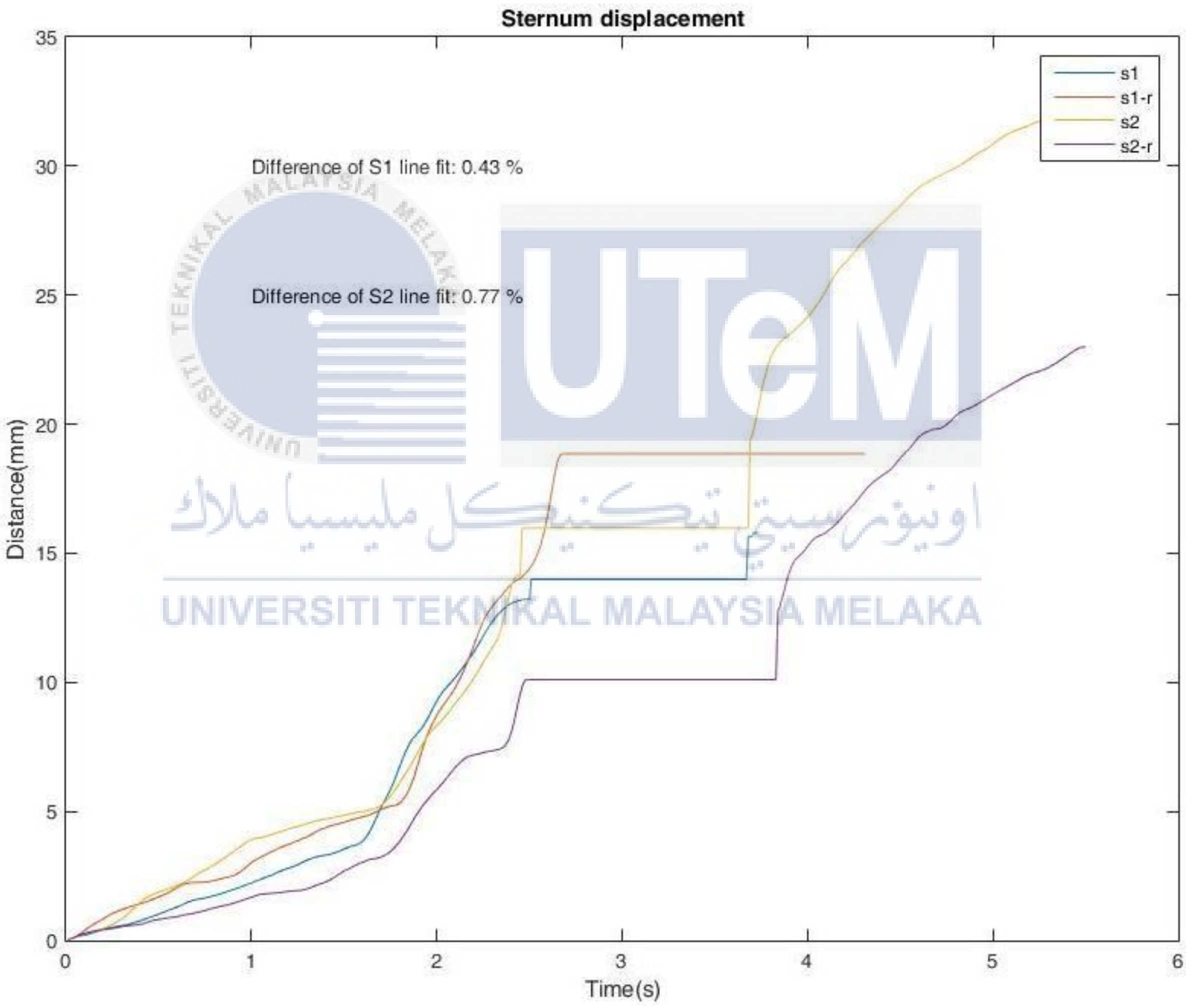


Figure 4.5 Sternum dislpacement for normal subject

4.6 Stroke angle evaluation

The graph presents the torso angle plot for lateral flexion, axial rotation and flexion for both subject 1 and 2, in normal and simulated stroke condition during the initiation of the task, which is cross-body reaching.

The torso angle plot for lateral flexion, axial rotation and flexion for normal subject 1 only exhibit minor mean differences which respectively, 1.01°, 0.62° and 0.13°, in between 2 repetition of the task. For subject 2, the angle plot also has small mean differences between each repetition as shown in Figure 4.7, which is 0.17°, 0.18° and 0.13° respectively. The data shows that there is a consistency in the torso angle obtained while carrying out the task in normal condition. The consistency of the angle can be achieved as there is no movement constraint in any of the body part involved for normal condition. This is proven by the graph in Figure 4.6 and Figure 4.7, that the average starting degrees of angle plot for lateral flexion, axial rotation and flexion for normal condition are almost at zero, which means that mostly only arms movement are involved while carrying the task. There is less trunk movement to compensate the lack of motor ability when it comes to cross-body reaching task for normal condition.

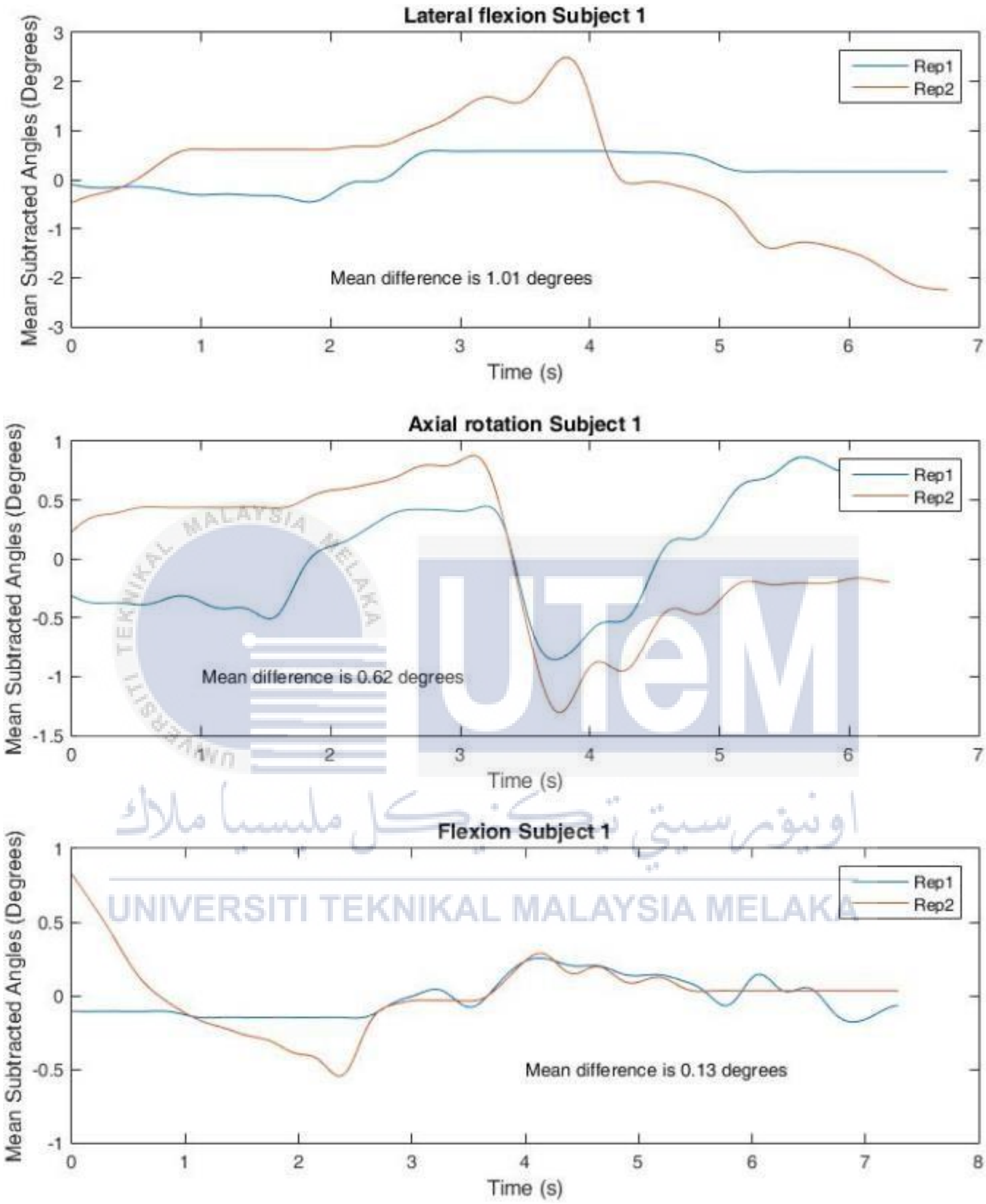


Figure 4.6 Subject 1 torso angle plot for normal

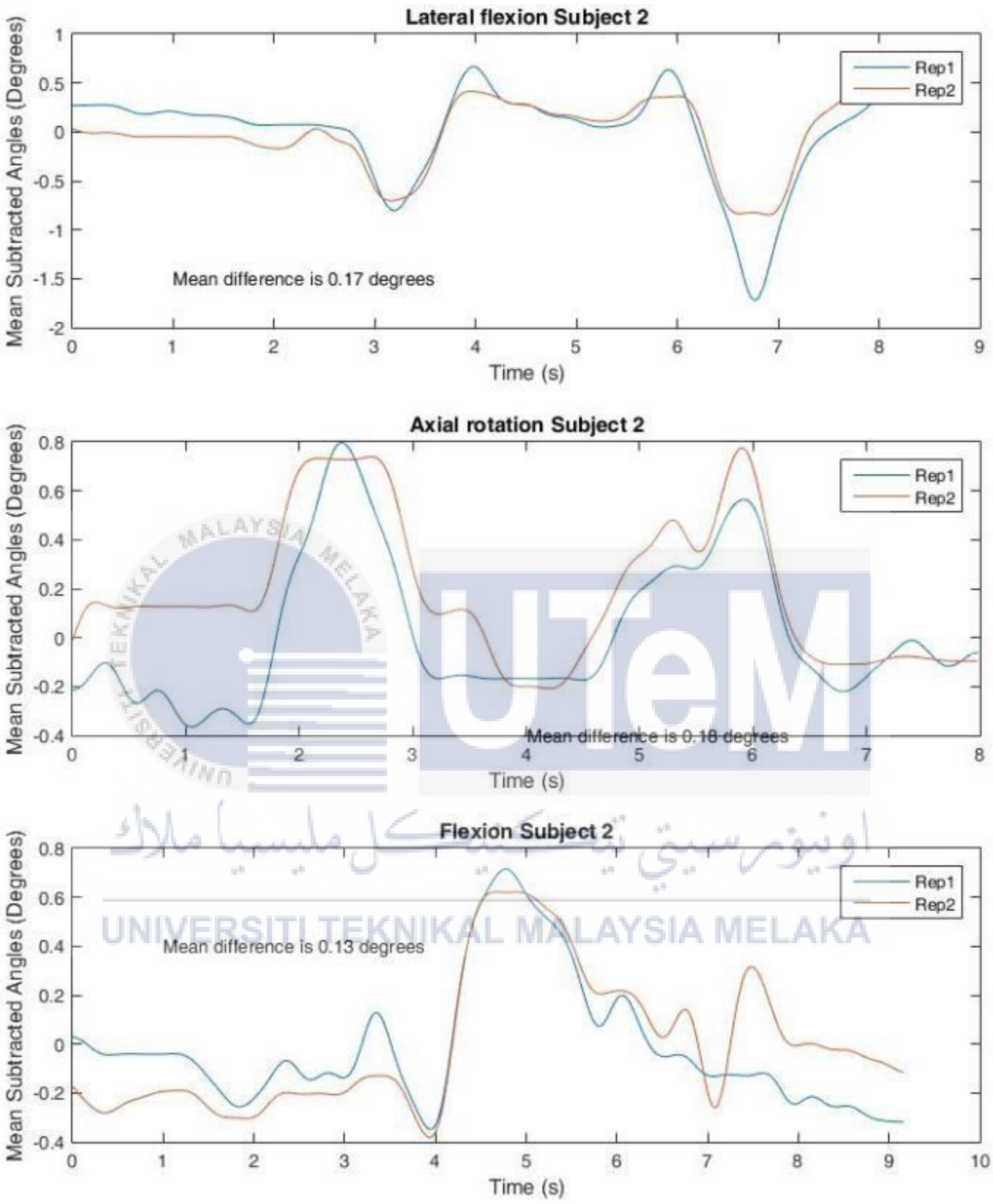


Figure 4.7 Subject 2 torso angle plot for normal

The torso angle plot for normal versus simulated stroke present a quite significant and more obvious mean difference. The graph color indicates the condition which blue represents the torso angle plot for normal and red represents the simulated stroke. As shown in Figure 4.8 and Figure 4.9, there is a huge difference in mean difference between the normal and simulated stroke for lateral flexion, axial rotation and flexion which is respectively 10.38°, 2.45° and 0.44°, for subject 1, then 15.67°, 0.28° and 1.09° for subject 2. The stroke travelled in an unstable condition from the beginning till the reaching point of the task. It means that the simulated stroke subject has issues in carrying out the task due to the limitation when the elbow brace is put on. In this simulated stroke, the subject was required to wear the elbow brace and was set to an elbow flexion of fixed 45°. As we can see from the graph, the simulated stroke subject did utilize lateral flexion, axial rotation and flexion, which also means the whole torso movement in order to compensate the lack of motor control and range of motion to perform the assigned task. Lateral flexion has the highest mean difference as the simulated stroke subject incorporate more of lateral flexion in order to finish the task. Axial rotation and flexion have relatively small mean difference for the torso angle plot, but the data is still distinguishable to compare when it comes to normal and simulated stroke movement.

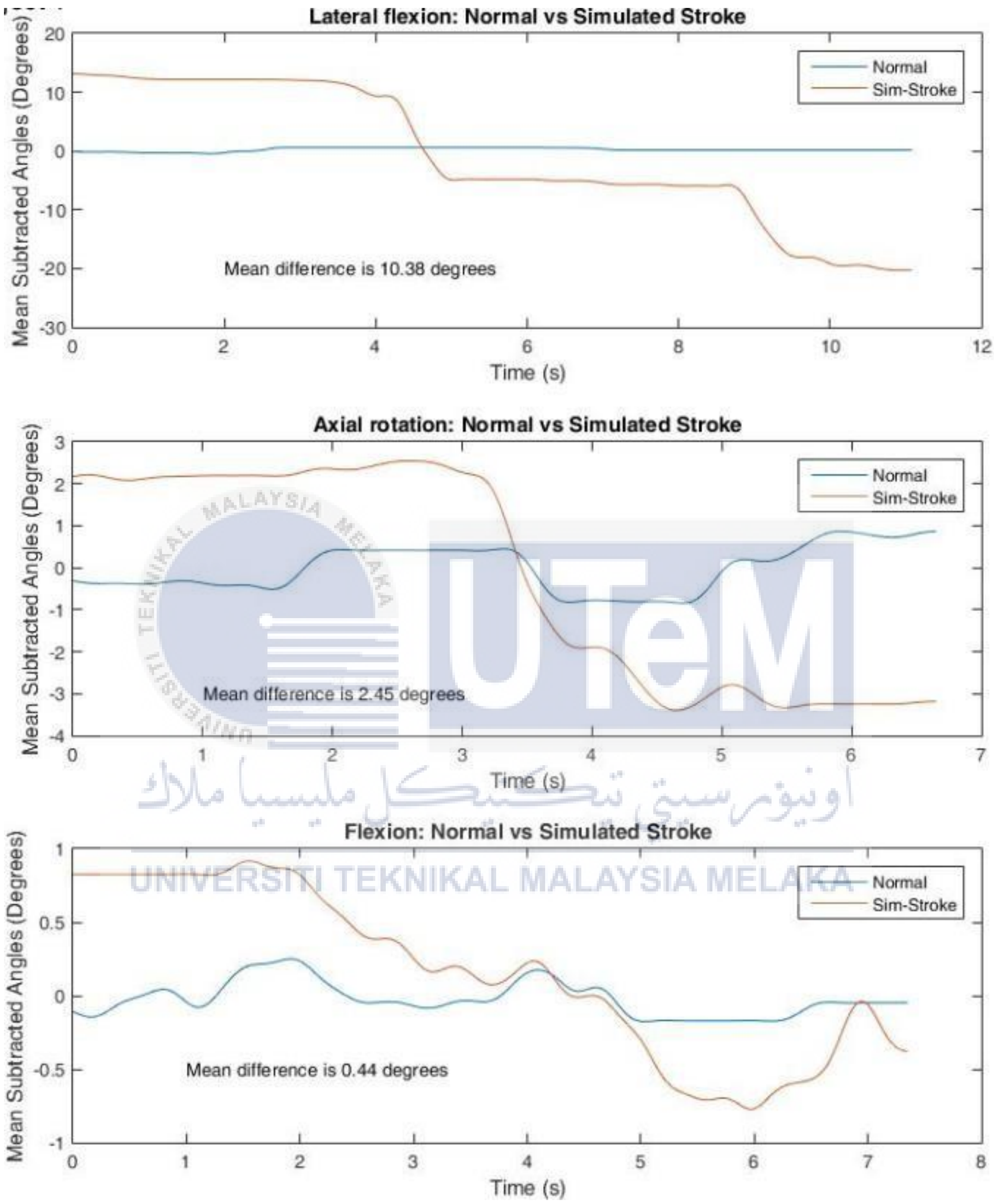


Figure 4.8 Subject 1 torso angle plot for normal versus simuated stroke

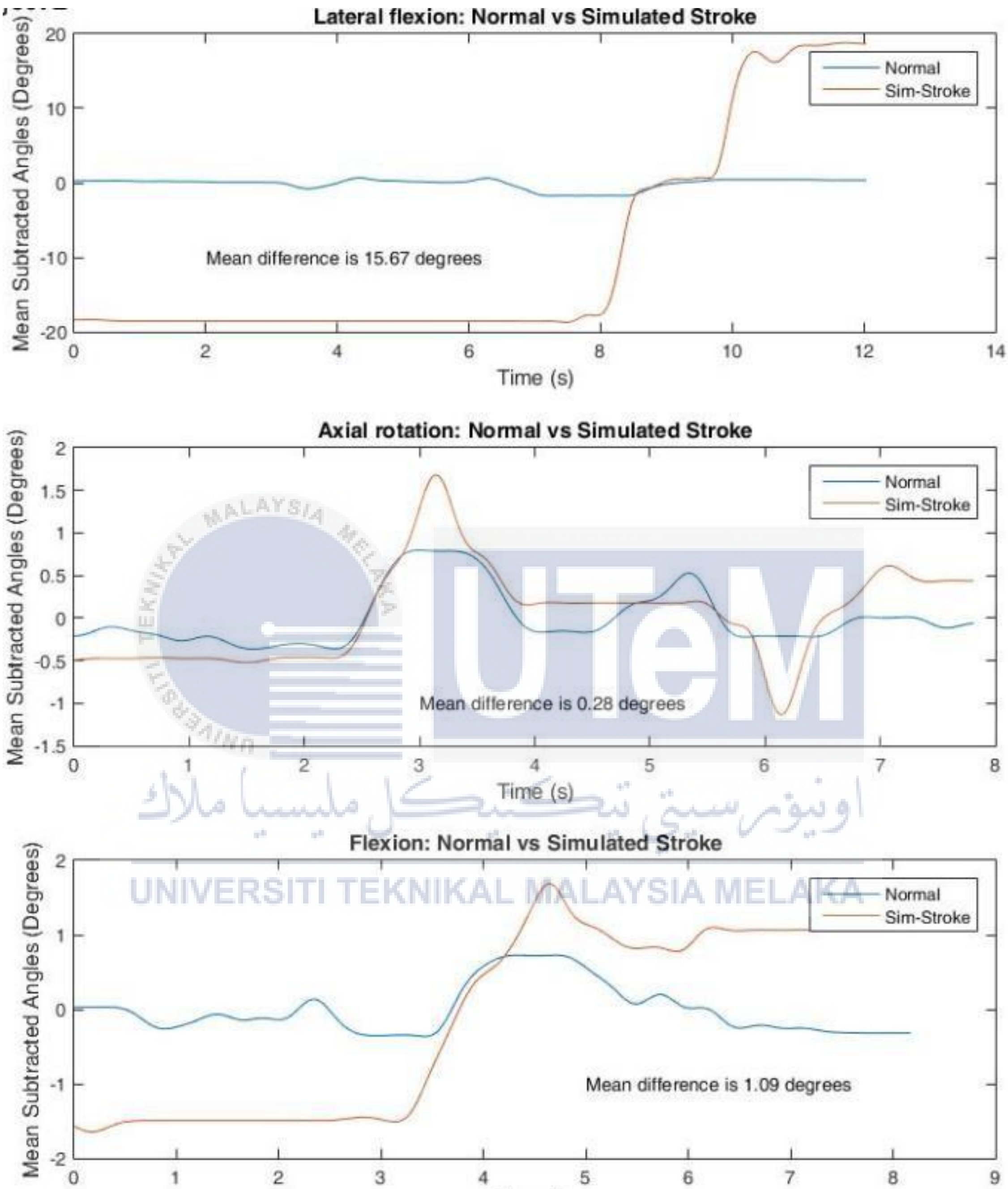


Figure 4.9 Subject 2 torso angle plot for normal versus simulated stroke

4.7 Summary

In this chapter, we can summarize that a suitable and optimum workplace have been prepared to initiate the experiment. Besides that, the camera has also been calibrated and the image error is within acceptable range. The hand tracing for both normal and simulated stroke data have been obtained. The data is then analyzed. Besides that, the data for cumulative sternum displacement also have been obtained and evaluated. Finally, the stroke angle for lateral flexion, axial rotation and flexion for the torso angle had been recorded and the data is analyzed.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

In conclusion, the first objective of this project is achieved. The B&L Engineering marker clusters set are proven to be a comprehensive marker model for torso movement. The model has been thoroughly studied and understand. It is light-weight, thin and rigid plastic fixtures. The cluster plates have extra holes for positioning the markers to meet the configurations requirements and the Velcro backing easily attaches to black neoprene wraps. The hand tracing for both normal subjects and simulated stroke subjects are shown in the different pattern obtain from the data of the recorded task, which also provide a better understanding of characteristics of the simulated stroke subject movements. Next, the second objective is achieved. The study showed that after some trials, data collection and data analyzation, the proposed marker model is simple if compare to the sternum displacement in terms of the product itself and its function thoroughly. When performing a task, the proposed marker model is convenient and simple with the configurations. It is less meticulous as the proposed marker model designed like a belt and it is easy to put on. Besides that, the proposed marker model application in the experiments produced reliable data. The study also showed the pattern differences between the normal and the simulated stroke in kinematic points of view which provide a better understanding of the reaching movements of the simulated stroke subjects.

5.2 Future Works and Recommendation

For the recommendation of this project, it is highly recommended that the experiment should be carried out in a wider and bigger workspace area with less object and obstacles around the environment. Reason is because the positioning of the camera needs to be further apart so that the field of vision will be wider. Besides that, it is recommended that any objects that is in the camera field of vision should be remove. Objects that can reflect infrared will produce undesirable pattern in the raw trial data during the task is being recorded. Other than that, the number of Vicon motion camera should be increase to 4 units as only 3 units are provided. To accurately track a marker, it is best that one single marker can be detected by two cameras at an angle. However, for the current camera setup, a certain position of the marker placed can only be detected by one camera. Thus, the marker will not be detected and recorded in the captured frame. Next, it is recommended that the lab is equip with multiple workstation. The workstation must include basic software such as Microsoft Office and advanced engineering software such as Matlab to further ease and improvise the research.

This project will give benefit in the field of biomechanics as well as the field robotics and science. The proposed model is simpler in term of functionality and minimum cost of implementation and percentage error. In the future, the analysis and work related the compensatory movement of stroke patients is highly improvised based on three aspects: accuracy, efficiency and consistency.

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APPENDICES

APPENDIX A GANTT CHART FOR FYP1

Project Activities of FYP 1	Week													
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
Briefing from supervisor	■													
Research and review paper	■	■	■											
Identifying marker model	■	■												
Setup field calibration at FKP		■	■											
Setup camera and parameters of field			■	■	■									
Calibration of software and hardware					■	■								
Trial run						■	■	■						
Data collection and analysis			■	■	■	■	■	■	■					
Final report preparation			■	■	■	■	■	■	■	■	■	■		
Presentation of FYP 1													■	
Submission of report FYP 1														■

APPENDIX B GANTT CHART FOR FYP 2

Project Activities of FYP 2	Week													
	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
Meeting with supervisor	■													
Further improvise data	■	■	■											
Recording raw trials data		■	■	■	■	■	■	■	■	■	■			
Preparing raw trials data						■	■	■	■	■	■			
Data collection								■	■	■	■	■		
Data analysis									■	■	■	■		
Final report preparation							■	■	■	■	■	■	■	
Presentation of FYP 2														■
Submission of report														■

APPENDIX C REFLECTIVE MARKER BROCHURE