REHABILITATION SUPPORT SYSTEM USING SHAPETAPE^{TM} SENSOR

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This thesis specially dedicated to my beloved parents

Nasaruddin bin Mat Khalim & Mahani binti Mat Isa

and all my family for all the encouragement and supports.

Thank You

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ABSTRACT

Nowadays, there are many rehabilitation support systems are proposed. Rehabilitation is a process of recovering human body to normal condition after an illness, injury or disease. This process requires continuous monitoring in order to provide the results. However, the existing rehabilitation support system has its own shortage. Firstly, the system needs fully supervised by specialist during the rehabilitation process. Secondly, patients lack of feedback about the effect of their rehabilitation process in real time. Lastly, the existing system have no offline data logging capabilities. The primary objective in this project is to monitor and analyze the movements behavior during rehabilitation process. The secondary objective is to evaluate the data movements in real-time and used the offline data for further analysis. The ShapeTape^{TM} sensor will be use as input device in this project to collect the data movements. The Shape Recorder software will provide the visual feedback on the PC before stored the data gained from the sensor in the offline system for deep analysis by specialist. In this project, rehabilitation support system will be focus on the human hand and leg.

ABSTRAK

Pada masa kini, terdapat banyak sistem sokongan rehabilitasi yang telah dicadangkan. Rehabilitasi adalah proses memulihkan badan manusia kepada keadaan normal selepas berlakunya kecederaan atau penyakit. Proses rehabilitasi ini memerlukan pemantauan yang berterusan untuk memberikan keputusan hasil daripada proses tersebut. Walau bagaimanapun, sistem sokongan rehabilitasi yang sedia ada mempunyai kekurangan yang tersendiri. Pertama, sistem sedia ada memerlukan pengawasan sepenuhnya oleh pakar semasa proses rehabilitasi. Kedua, pesakit kekurangan maklum balas mengenai kesan proses rehabilitasi yang dilalui dalam masa yang nyata. Akhir, sistem yang sedia ada tidak mempunyai keupayaan menyimpan data secara luar talian. Objektif utama projek ini adalah untuk memantau dan menganalisis tingkah laku pergerakan pesakit semasa proses rehabilitasi. Objektif sekundernya adalah untuk menilai data pergerakan pesakit dalam masa nyata dan menggunakan data luar talian untuk analysis lanjut oleh pakar. Sensor *ShapeTape*^{TM} digunakan sebagai alat pengesan dalam projek ini untuk mengumpul data pergerakan. Kemudian, perisian *Shape Recorder* akan memberi maklum balas secara visual pada PC dan data yang diperolehi daripada sensor akan disimpan di dalam sistem luar talian untuk dianalisis oleh pakar. Sistem sokongan rehabilitasi dalam projek ini akan ditumpukan pada bahagian tangan dan kaki.

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LIST OF ABBREVIATIONS

3D	Three Dimensional
EMG	Electromyogram
MEMS	Microelectromechanical
PC	Personal Computer
ADL	Activities of Daily Living
OLE	Optical Linear Encoder
ROM	Range of Motion
DOF	Degree of Freedom
LED	Light Emitting Diode

CHAPTER 1

INTRODUCTION

This chapter will cover about the introduction of rehabilitation, project background, problem statements of the project, objectives and project scope.

1.1 INTRODUCTION OF REHABILITATION

Rehabilitation is the process of helping an individual achieves the highest level of function, independence, and possible quality of life [1]. This process requires the patients to do repetition physical exercises and continuous monitoring in order to knowing their improvement rate.

1.2 BACKGROUND OF STUDY

Healthcare is the challenging issues for many countries due to increasing of aging population over time and people living with chronic disease [2]. The functional status is important especially for elderly and chronic disease. Physical activity plays an important role in improving the human health[. Physical activity has been defined as any bodily movement produced by skeletal muscles that results in energy expenditure [2]. Monitoring daily activities are the best platform for assessing the changes in body physical and behavior. Physical activity in daily life can be categorized into sitting standing, lying, walking, running etc. Transition between activities can present pattern that indicate the quality of movement.

1.2.1 HUMAN BODY SYSTEM

Human body system is a collective of functional unit made by several organs in which the organs work in complete coordination with one another. It is made of ten different systems. Every systems need support of other system to maintain the human healthy. If one of these system is not functioning, it will lead human to death.

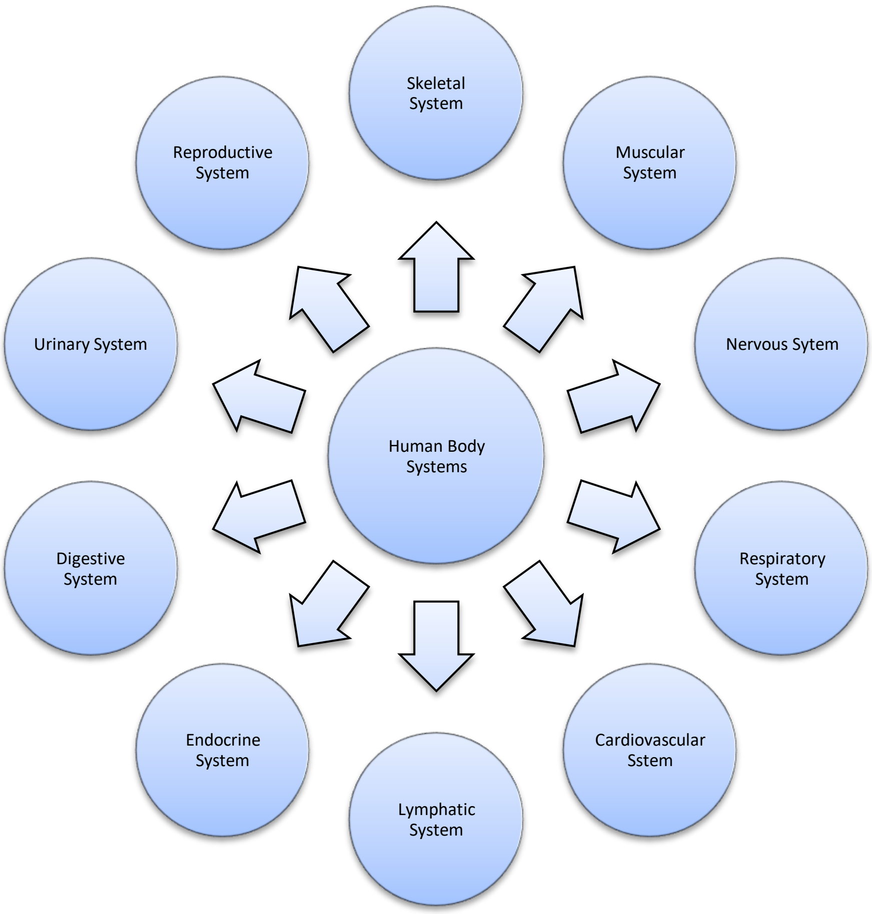

Figure 1.1: List of Human Body Systems

In this project focused on human skeletal system. Skeletal can be defined as the hard framework of human body. Skeletal system consists of bones, associated cartilages and joints. Bone is a tough and rigid from of connective tissue. Cartilage also a form of connective tissue but not tough and rigid as bone. Joints are important components of human skeleton because they make the human skeleton move freely. Human skeletal system functioning as gives strength, support, shape, protection and cell production.

1.2.2 APPROACHES FOR HUMAN MOVEMENT SYSTEM

The existing movement systems has used different approaches to improve the human healthcare. Mostly approaches used are video based system, wearable sensor based and environmental sensor based [2].

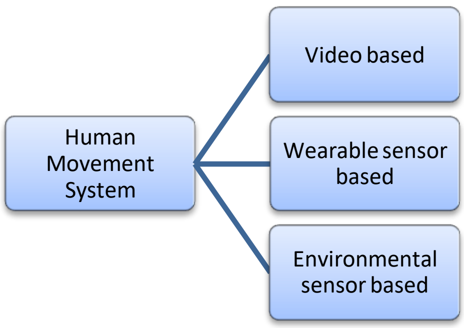

Figure 1.2: Systems approaches for human movement system

Video based system: These systems use camera for tracking and recognize physical activity. This system often works fine in laboratory but fails under a real home setting because of varies circumstance such as lighting. In additional, the device such as camera are mostly expensive [2].

Wearable sensor based: Systems are designed to continuously measure data for the recognition of daily human activities. These system requires repetition motion of the human body. Wearable sensors are suited to collect data on daily activity patterns because they can be worn on body [2].

Environmental sensor based: Systems are developed to monitor the interaction between users and their home environment. These system is a distributing of ambient sensors throughout the patient living environment. However, such systems are infrastructure dependent and cannot monitor a subject outside of the home setting [2].

This project focused on wearable sensor based to detect movement during the patient doing their activities of daily activities.

1.2.3 SHAPETAPE™ SENSOR OVERVIEW

Shapetape™ sensor is a light weight, wearable, and flexible ribbon that uses it own software which is Shape Recorder to create a 3D computer image and data set of its shape in real time, based on bend and twist information from an array of fiber optic sensors along its length. The application of this sensor are it follows human arm, leg, back, and neck movements for motion capture, virtual reality, biomedical, gaming and robotic control.

Figure 1.3: ShapeTAPE™ Sensor

1.3 PROBLEM STATEMENTS

Recently, many system for rehabilitation systems has introduced for improving human health. However, the existing rehabilitation systems has its own shortage to improve in future work. The first problem is rehabilitation process needs continuous monitoring by physical therapist in order to provide the results. In other meaning, the system is not portable to used at other places except hospital and without the presence of a specialist. Next problem is rehabilitation process requires the patients to do repetitive physical exercises without knowing their improvement rate. This may cause them loss interest to complete the rehabilitation process. Other issues is the system do not have offline data for the clinician do further analysis.

1.4 OBJECTIVES OF STUDY

The objectives for this project are:

- To identify and analyze the movements behaviour of patient during rehabilitation process.
- To evaluate and interpret the data of movements during rehabilitation in real-time and used the offline data for further analysis by a doctor.

1.5 SCOPES OF STUDY

This project focuses on identify and analyze of patients movement behavior during daily activities using ShapeTape^{TM} sensor with different type of activities. In this project the sensor is placed on targeted positions such as arms and legs to evaluate. Then, the data collection will be displayed and recorded using Shape Recorder software. Once the results are displayed and recorded, the comparison will be made to declare the performance status of the patient.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter show the types of rehabilitation. Then discussed the overview of the anatomy of the arm and leg and followed by a review of rehabilitation support system approach.

2.2 OVERVIEW THE TYPES OF REHABILITATION

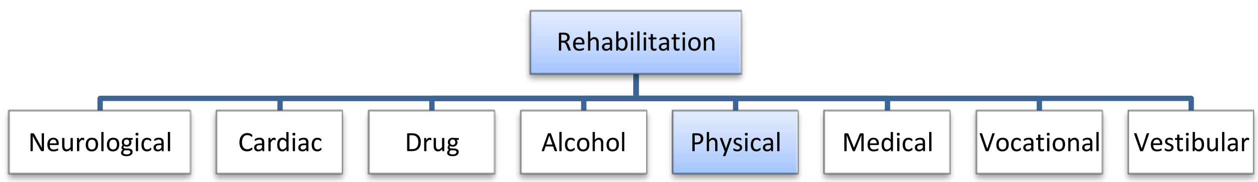

Figure 2.1: Types of Rehabilitation

In this project focused on the physical rehabilitation for the arm and leg. Physical rehabilitation is a continues process of evaluating the patients with functional impairment due to disease or injury.

2.3 ANATOMY OF THE UPPER BODY AND LOWER BODY

Upper body strength is important because it will control our body ability to perform everyday activities such as lying, pulling, pushing and lifting. Having a good strength of upper body show the improvement of our flexibility, mobility and range of motion. In the human arm anatomy its divided into two parts which are the upper and lower portion. The upper portion is the elbow and above while for lower portion is the elbow and below. The upper portion is called as upper arm whereas the lower portion known as forearm.

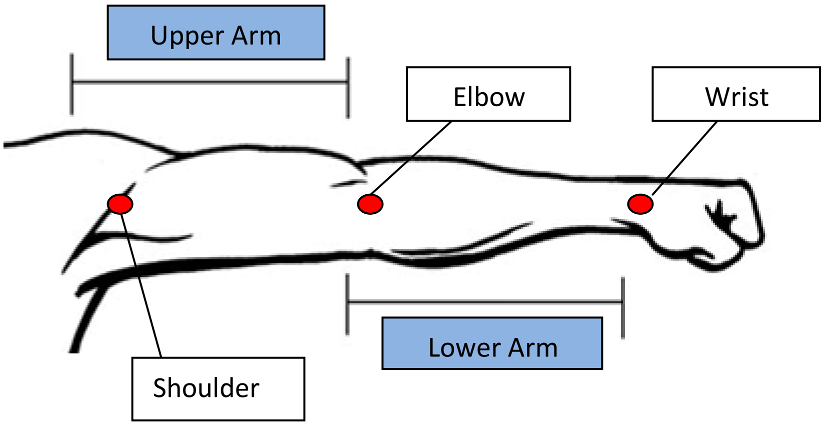

Figure 2.2: Illustration of human arm

Human arm consists three main bones which are humerus, radius and ulna. The primary function of all the bones is allowing the motion and supporting the arm. The humerus is the bone that located between the shoulder and the elbow. The is very important for movement because it have many ligament and muscle attachment. The radius is lower arm that extending from the elbow to the wrist. This bone parallel with the ulna. The ulna is the final bone of the arm.

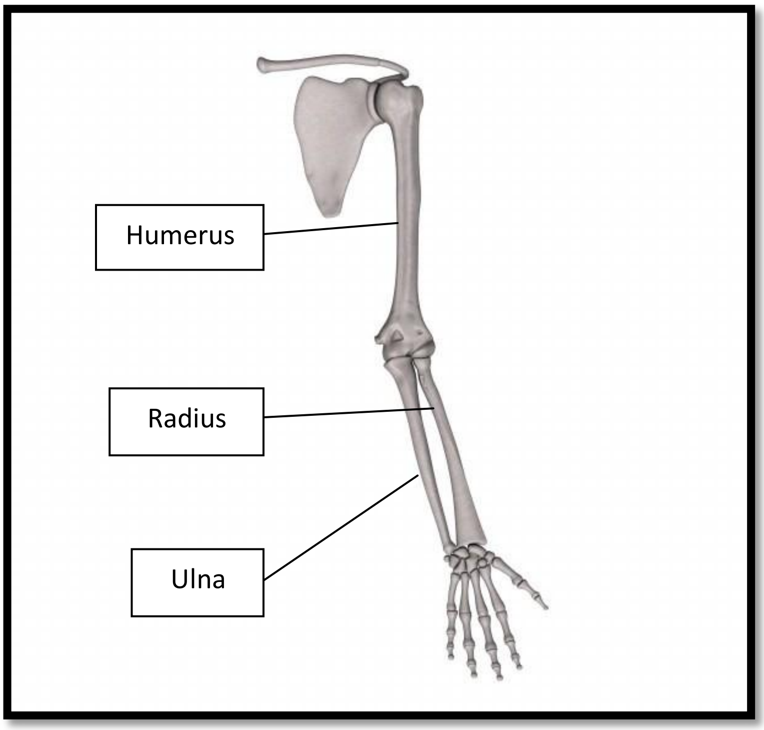

Figure 2.3: The position of arm bones

Human leg consists of five section which are upper leg, knee, lower leg, ankle and foot. The first section is upper leg position located between the hip and the knee. At this section have only one bone which is femur. The second section is knee. Knee is act like a pivot that connect the upper and lower leg. At the lower leg section consists two bones which are tibia and fibula Tibia bone will meets the femur to create the knee and the fibula will connected with tibia at the knee joint. Then ankle is point of tibia and fibula meet the foot. Ankle important for movement and balance. The last section is foot with the complex structure.

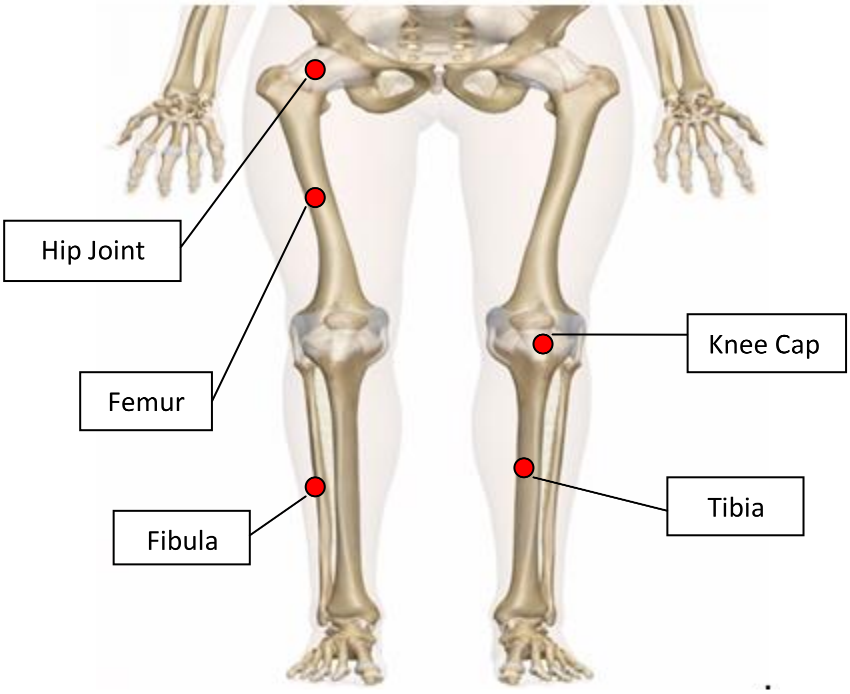

Figure 2.4: The position of leg bones

2.4 REVIEW OF REHABILITATION SUPPORT SYSTEM

Dao *et al* in their work titled interactive and connected rehabilitation systems for e-health [3] applied Kinect and EMG Shimmer sensor to get kinematics data of the human body. This system provide bio-feedback information of internal and external behavior of the musculoskeletal system during rehabilitation process. They focused on the rehabilitation exercises of the lower limb.

Based on Radzi *et al*, they implemented multi sensor (flex sensor, force sensitive sensor and accelerometer) for a portable arm rehabilitation monitoring device [4]. This device can be utilize at home with minimal supervised from physical therapist. The data logging system for this device can store the data for the certain time in the PC.

Karolina *et al* introduced motion capture systems in their paper with the titled digital human model and motion capture techniques for home kinesitherapy [5]. In this paper their compared two systems which are ShapeWrap II and Microsoft Kinect sensor. The aims of their studied are for monitoring home kinesitherapy without specialist but each patients have their private account data for doctor access and monitoring the progress.

According to Alan *et al* [6] to improved rehabilitation process, they introduced human interactive system with implemented the games. In this system two games are introduced to make more accessible for improvement in rehabilitation. The games system will provide the feedback by showing the score on the screen to keep the patients motivated.

Louis *et al* [7] they used wearable accelerometers for assessing changes in physical and behavior for the elderly and the patients with chronic diseases. In this system the patients is evaluated by their daily living activities.

Paper with the title real-time human daily activity recognition through fusion of motion and location data by Chun Zhu *et al* [8] proposed an approach to indoor human daily activity. This system combines motion data and location information. They applied one inertial sensor worn on the right tight of human subject to collect motion data, while for record human location information they used an optical motion capture system. In recognizing activity based on motion data, two algorithms is proposed which are neural networks and hidden Markov model. The location information used Bayes' theorem to update the activities recognized from motion data.

Based on paper by Aizan *et al* [9], they developed system for measuring body joint angles focused on the knee. Their system consists of multiple flex-sensors mounted on a supportive cloth and microelectromechanical system (MEMS) vibratory gyroscope. This system function is to monitor the movement during patients do their exercises. In evaluation of knee angle movement were estimated by using Kalman Filter from the data measured by sensors.

Chikamune *et al* [10] have been developed a system which assists walking rehabilitation. Their system is a shoe-type device which consists of sensor unit (gyro sensor, acceleration sensor, ultrasonic sensor and pressure sensor). This system used wireless module to collect data of gait information (step length, step width, pressure, etc) from the shoe-type device and send to a personal computer. These gait data information will be used to displayed on the screen for the doctor, physical therapist and patient can know the performance of the gait based on the information shown on the screen.

Paper with the title development of rehabilitation support system for lower limbs for recovery and quantitative evaluation of proprioception by Daichi *et al* [11] have been developed a new rehabilitation support system for "sensory training". In this system applied video games as test programs. The measurement are taken one time before the operation and once or more until patient are discharged from the hospital. Quantitative evaluation are taken by gravicorder test and 10 meter walking test. In this training, the patient's upper limbs are displayed on a PC monitor in order to give the information feedback.

Based on paper by Hong *et al* [12], they designed a soft wearable exoskeleton glove called "ExoGlove" embedded with pneumatic actuators of variable stiffness for hand assistive and rehabilitation. In assistive mode, this glove is able to perform activities of daily living (ADLs) such as hand grasping and pinching, while for rehabilitation mode it able to perform different repetitive tasks in order to achieve continuous passive motion exercises. This glove consists of main body which are glove, Velcro straps and customizable pneumatic actuators with variable stiffness. The variable stiffness function is to achieve different hand motions required in various physical therapy exercises by adjusting it in different localities.

Nguyen *et al* [13] have been integrated the optical linear encoder (OLE) based system and an accelerometer to capturing the human arm motion. This system consists of three sensing modules of OLE placed at shoulder joint, elbow joint and wrist joint. The information provided by the OLE will be used to estimate joint angle. The combination of accelerometer with a OLE privides a complete system, which is able to track orientations, accelerations and joint angles. Then, in order to track the arm movement, the sensing modules is connected by controller area network.

Daponte *et al* [14] in their paper with title a wireless-based home rehabilitation system for monitoring 3D movements presents the design and implementation of a home rehabilitation system. The wireless system is for measuring the range of motion (ROM) of patients performance during exercises. In order to allow real-time 3D reconstruction of patient motion, this system will be interacting with ROM analysis software. The present of this software allow the clinical staff to directly interface and watch the movements without leaving the workplace.

In order to capture the motion of stroke rehabilitation a mobile and wireless inertial sensor called Institute of Microelectronic Systems Inertial Measurement Unit $(IM)^2SU$ platform is proposed [15]. Sensor fusion on an 8-bit MCU is enabled by algorithmic modifications of the utilized Kalman filter. The platform consists of hardware part and software part, which provide high orientation, estimation accuracy, low costs, a platform independent, wireless connection and extensibility Then the proposed system is compared with the Xsens MTx sensor.

A smart phone based system is serve as the platform for integrating an accelerometer-based sensor network [16]. This system is for monitoring the performance in rehabilitation exercises by patients with shoulder injuries. Two accelerometer are implemented in this system, one sensor and smart phone is placed on the affected shoulder and another one on the chest. This two sensor will communicate using Bluetooth application. Five monitoring exercises are conducted and it will be recognized by the Support Vector Machine algorithm and recorded on the smart phone. All these records can be used as a reference of patients activity.

Markopoulos *et al* [17] in their paper applied Us'em wearable device to motivate stroke patients towards increasing the use of their impaired arm in everyday life activities.

This device will monitors a patient's behavior in order to provide a feedback. This system consists of two parts, a wristband-like for monitor and watch-like for graphical feedback on a small screen. Us'em provides feedback to patients regarding the ratio of movement of impaired arm compared to healthy arm.

Aung *et al* [18] in their paper proposed system that can be used at both places either home or rehabilitation centre. This system consists two modules namely as rehabilitation exercise module and real-time muscle simulation module. Some Augmented Reality (AR) games are developed as rehabilitation exercises for more interact with real environment. The patients are able to interact with the rehabilitation exercise easily via worn colour marker and follow the instruction to complete the game. Then integrated with real-time muscle simulation to complete the system based on patient's electromyography (EMG) signals.

Carolina *et al* [19] in their paper presents a set of serious games for assessment and rehabilitation. This system is proposed for ankle rehabilitation. Two games are developed based on virtual therapy. The first one to stimulate and evaluate dorsiflexion range of motion while the second one for muscle strength. The continuous use of the system can increase muscle force, motor control and sensor motor coordination, improving the walking pattern and avoiding the drop foot.

Kikuchi *et al* [20] developed 6-degrees-of-freedom (DOF) upper rehabilitation support system to evaluate the pattern of pattern of stroke survivors named "Robotherapist". This system applied robot technology and virtual reality technology. This system can control and measure both the position and posture of the hand of the operator, and present force sense including the wrist torque to the operator according to situations of the application software.

Sheng Lin *et al* [21] in their paper developed a computer game for machine integrated rehabilitation training system. This system provide rehabilitation games to allows patients do hand grasp-and-place movement. Images are captured by a double-CCD camera, and then the positioned will displayed on a large screen. Training can be set depending on the circumstance on each patients.

According to paper by Jovanov *et al* [22] they implemented wireless body area network (WBAN) for computer-assisted physical rehabilitation and monitoring. Several sensor are applied in this system such as tilt sensor, motion sensor and ECG. This system will provide real-time data analysis of sensor data, guidance and feedback to the patients. All recorded data can be transferred to medical server via internet.

2.5 CONCLUSION

After reviewing the variable techniques from the previous project, this project proceed by performing the motion capture system using ShapeTape™ sensor. This system will provide the raw output with xyz position when doing activity such as standstill, walking, running and lifting.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

In this chapter describes the overview of overall system operation, steps to motion capture using Shape Recorder software and the experimental setup.

3.2 OVERVIEW SYSTEM OPERATION

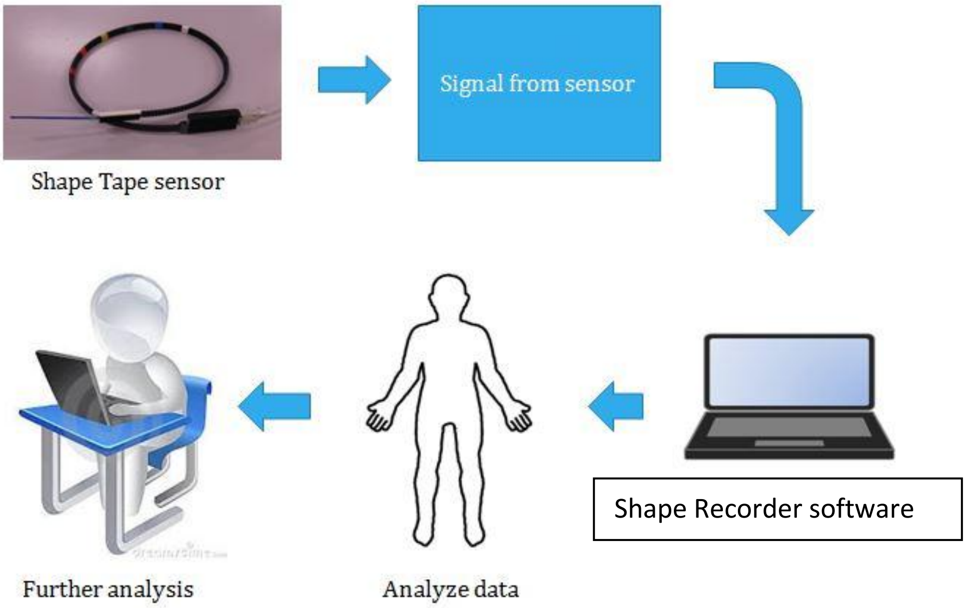

Figure 3.1: Overview system.

From the Figure 3.1 shows how the overall system is function. First of all the ShapeTape^{TM} sensor is worn by the subject either at their arm or leg based on activities provided. Then the subject will undergoes all the activities to give the output on the Shape Recorder software in real-time which is the patient can see their movement on the screen. This sensor will provide the output with the XYZ position along the sensor. From this XYZ position, the data will convert to angular by using the Microsoft Excel.

3.3 STEPS TO MOTION CAPTURE USING SHAPE RECORDER SOFTWARE

Figure 3.2(a)

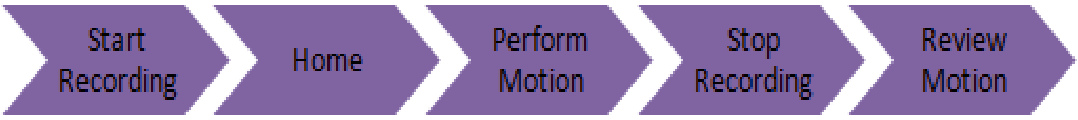

Figure 3.2(b)

Figure 3.2(a) and Figure 3.2(b): Steps to Motion Capture

As shown in the Figure 3.2(a) and 3.2(b) are the steps need to followed for capture the motion using the Shape Recorder software. The steps in Figure 3.2(a) only needs to perform once per session while for the steps in Figure 3.2(b) needs to perform every recording is make.

3.4 EXPERIMENTAL SETUP

In order to get the data, the Shapetape^{TM} sensor is used. Three number of subjects will be recruit to be wearing this sensor on their body as shown in Figure 3.3 and Figure 3.4 below. At a certain place along the Shapetape^{TM} will be attach to a Velcro band as shown in Figure 3.5 for make the subject feel easy and comfortable.

Figure 3.3: Sensor position at leg

Figure 3.4: Sensor position at arm

Figure 3.5: Velcro band

The physical activities can be classified into four groups of activity as given in the compendium of physical activities The four basic daily activities are stated in the following table are focusing on the shoulder and wrist gesture of movement for arm. While for leg focusing on hip, knee and ankle.

Table 3. 1: Classification of physical activities activity group

Physical Activity	**Activity Group**
Standstill	Very low level activity
Walking	Low level activity
Lifting object	Medium level activity
Runnng	High level activity

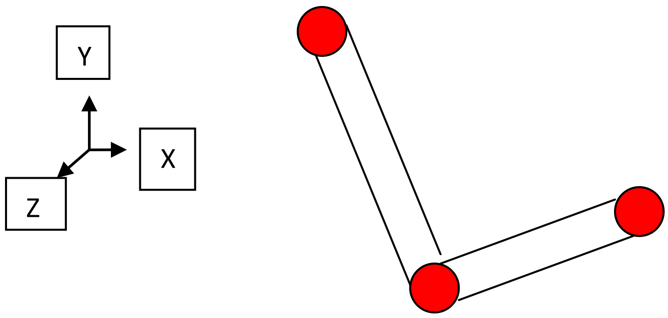

Figure 3.6: Illustration of arm based on side view

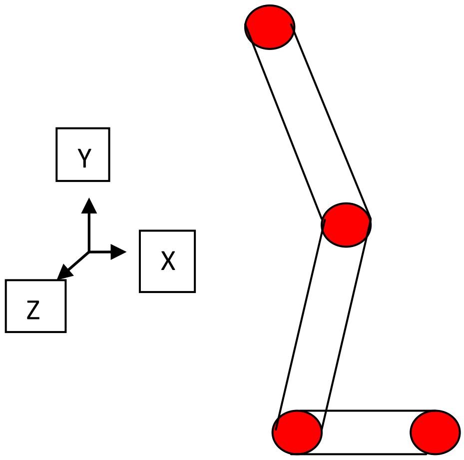

Figure 3.7: Illustration of leg based on side view

3.5 CALCULATION TO FIND ANGLE OF VECTOR IN 3D

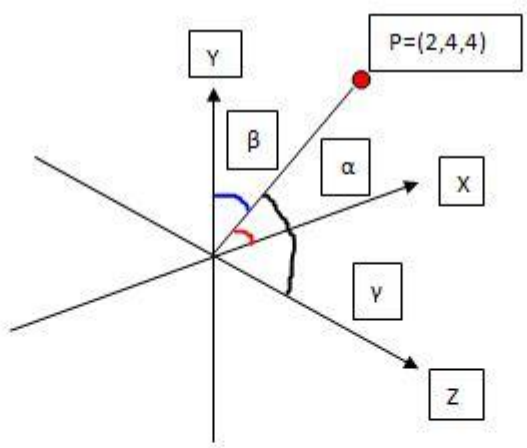

Figure 3.8: Isometric view of XYZ plane

Based on Figure 3.8 shows the isometric view of XYZ plane. The red arc shows the angle (α) between the real position, P to the x-axis while the blue arc is angle (β) between the real position P to the y-axis. Then the black arc is the angle (γ) between the real position P to z-axis.

Example calculation based on the real position P in Figure 3.8:

Find Magnitude |P|,

$|P| = \sqrt{(2^2) + (4^2) + (4^2)}$

|P|=6

Find angle of α, β and γ,

$$\cos \alpha = \frac{Px}{|P|}$$

$\alpha = 70.53°$

$$\cos \beta = \frac{Py}{|P|}$$

$\beta = 48.19°$

$$\cos \gamma = \frac{Pz}{|P|}$$

$\gamma = 48.19°$

CHAPTER 4

RESULT AND DISCUSSION

4.1 INTRODUCTION

In order to achieve the proposed objectives of this project, several activity are selected such as standing still, walking, running and lifting. The results obtained from this project will be compared with the source data and the previous project.

4.2 SENSOR TESTING

Figure 4.1: The red LED show the sensor is on

Figure 4.2: Sensor position along the tape

Figure 4.1 shows the battery part of the sensor. The red LED indicate there is have power supply while for Figure 4.2 shows the sensor located on the tape. The length of the sensor along the tape is 720mm from point 1 to point 2.

4.3 SOFTWARE TESTING

In this project the Shape Recorder software will be used to record the movement behavior visually. First of all, before start the recording the subject file need to update as shown in Figure 4.3. When the system start to recording the motion the raw data will sending and save into the computer memory. Initially this software will display the value of position for the XYZ for each point along the tape. Based on this raw data has be saved, the data can be insert it manually into Microsoft Excel in order to finding the angular values and generate a proper graphical display.

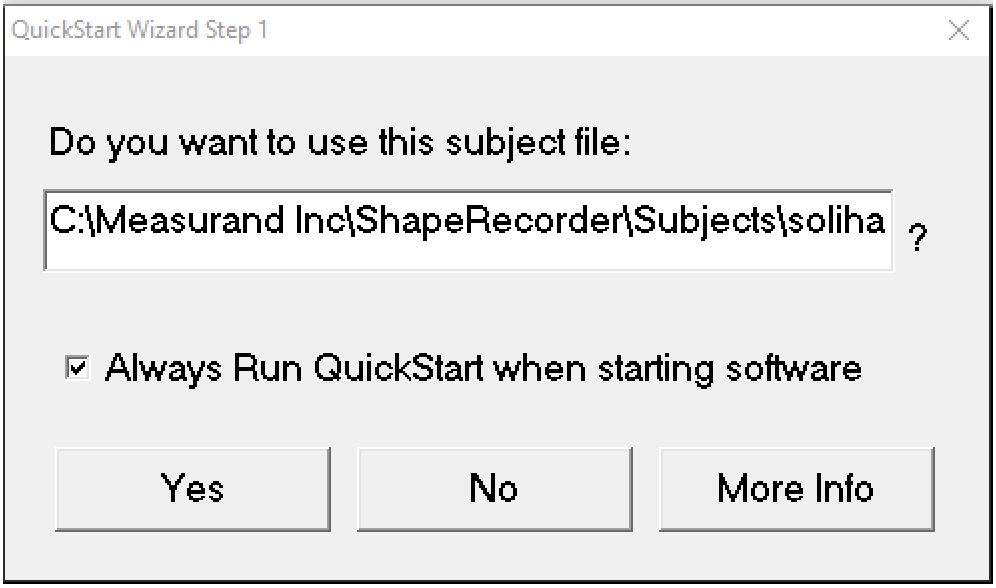

Figure 4.3: The update of subject file

E	F	G	H	I	J	K	L	M	N	O	P	Q
X10994_01(mm	Y10994_01(mm	Z10994_01(mm	X10994_02(mm	Y10994_02(mm	Z10994_02(mm	X10994_03(mm	Y10994_03(mm	Z10994_03(mm	X10994_04(mm	Y10994_04(mm	Z10994_04(mm	X10994_05(mm
-0.24	36	0	-1.21	71.99	0	-2.11	107.97	0	-2.61	143.97	0	-3.32
-0.24	36	0	-1.21	71.99	0	-2.11	107.97	0	-2.62	143.97	0	-3.32
-0.24	36	0	-1.21	71.99	0	-2.11	107.97	0	-2.62	143.97	0	-3.32
-0.24	36	0	-1.21	71.99	0	-2.11	107.97	0	-2.62	143.97	0	-3.32
-0.24	36	0	-1.21	71.99	0	-2.11	107.97	0	-2.62	143.97	0	-3.33
-0.24	36	0	-1.21	71.99	0	-2.11	107.97	0	-2.62	143.97	0	-3.33
-0.24	36	0	-1.21	71.99	0	-2.11	107.97	0	-2.62	143.97	0	-3.33
-0.24	36	0	-1.21	71.99	0	-2.11	107.97	0	-2.62	143.97	0	-3.33
-0.24	36	0	-1.21	71.99	0	-2.11	107.97	0	-2.62	143.97	0	-3.32
-0.24	36	0	-1.21	71.99	0	-2.11	107.97	0	-2.62	143.97	0	-3.32
-0.24	36	0	-1.21	71.99	0	-2.11	107.97	0	-2.62	143.97	0	-3.31
-0.24	36	0	-1.21	71.99	0	-2.1	107.97	0	-2.61	143.97	0	-3.3
-0.24	36	0	-1.21	71.99	0	-2.1	107.97	0	-2.61	143.97	0	-3.28
-0.24	36	0	-1.2	71.99	0	-2.09	107.97	0	-2.59	143.97	0	-3.26
-0.24	36	0	-1.2	71.99	0	-2.08	107.97	0	-2.57	143.97	0	-3.23
-0.24	36	0	-1.19	71.99	0	-2.07	107.97	0	-2.55	143.97	0	-3.2
-0.24	36	0	-1.18	71.99	0	-2.05	107.98	0	-2.53	143.97	0	-3.17
-0.23	36	0	-1.17	71.99	0	-2.03	107.98	0	-2.5	143.97	0	-3.12
-0.23	36	0	-1.16	71.99	0	-2.01	107.98	0	-2.46	143.97	0	-3.08
-0.23	36	0	-1.15	71.99	0	-1.99	107.98	0	-2.43	143.97	0	-3.02
-0.23	36	0	-1.14	71.99	0	-1.96	107.98	0	-2.39	143.97	0	-2.97
-0.23	36	0	-1.13	71.99	0	-1.94	107.98	0	-2.35	143.98	0	-2.91
-0.22	36	0	-1.11	71.99	0	-1.91	107.98	0	-2.31	143.98	0	-2.86
-0.22	36	0	-1.1	71.99	0	-1.88	107.98	0	-2.26	143.98	0	-2.8
-0.22	36	0	-1.09	71.99	0	-1.86	107.98	0	-2.23	143.98	0	-2.75
-0.22	36	0	-1.08	71.99	0	-1.83	107.98	0	-2.19	143.98	0	-2.71
-0.21	36	0	-1.06	71.99	0	-1.81	107.98	0	-2.15	143.98	0	-2.66
-0.21	36	0	-1.05	71.99	0	-1.78	107.98	0	-2.12	143.98	0	-2.62
-0.21	36	0	-1.04	71.99	0	-1.76	107.98	0	-2.08	143.98	0	-2.58
-0.2	36	0	-1.02	71.99	0	-1.73	107.98	0	-2.04	143.98	0	-2.53
-0.2	36	0	-1.01	71.99	0	-1.7	107.98	0	-2.01	143.98	0	-2.49
-0.2	36	0	-0.99	71.99	0	-1.68	107.98	0	-1.97	143.98	0	-2.45

Figure 4.4: Example of raw data in Microsoft Excel

4.4 DATA SOURCE FROM JOURNAL

Table 4.1: Standstill data

Time (s)	X1 (Angle)	Y1 (Angle)	Z1 (Angle)	X2 (Angle)	Y2 (Angle)	Z2 (Angle)
1	288.23	295.02	234.78	190.3	202.69	203.5
2	288.23	295.02	234.78	190.3	202.69	203.5
3	288.23	295.02	234.78	190.49	202.17	204.44
4	288.23	295.02	234.78	189.29	202.69	201.37
5	288.23	293.43	234.78	190.49	202.17	204.44
6	288.23	293.43	234.78	189.29	201.8	202.25
7	288.23	293.43	234.78	190.3	200.9	205.46
8	288.23	295.02	234.78	190.49	202.17	204.44
9	288.23	293.43	234.78	190.49	202.17	204.44
10	288.23	295.02	234.46	190.49	201.25	205.46
11	288.23	295.02	234.78	190.49	202.17	204.44
12	288.23	295.02	234.78	190.49	201.25	205.46
13	288.23	295.02	234.78	190.49	202.17	204.44
14	288.23	293.43	234.78	190.3	202.69	203.5
15	288.23	293.43	234.78	190.3	202.69	203.5
16	288.23	295.8	234.78	190.49	203.07	203.5

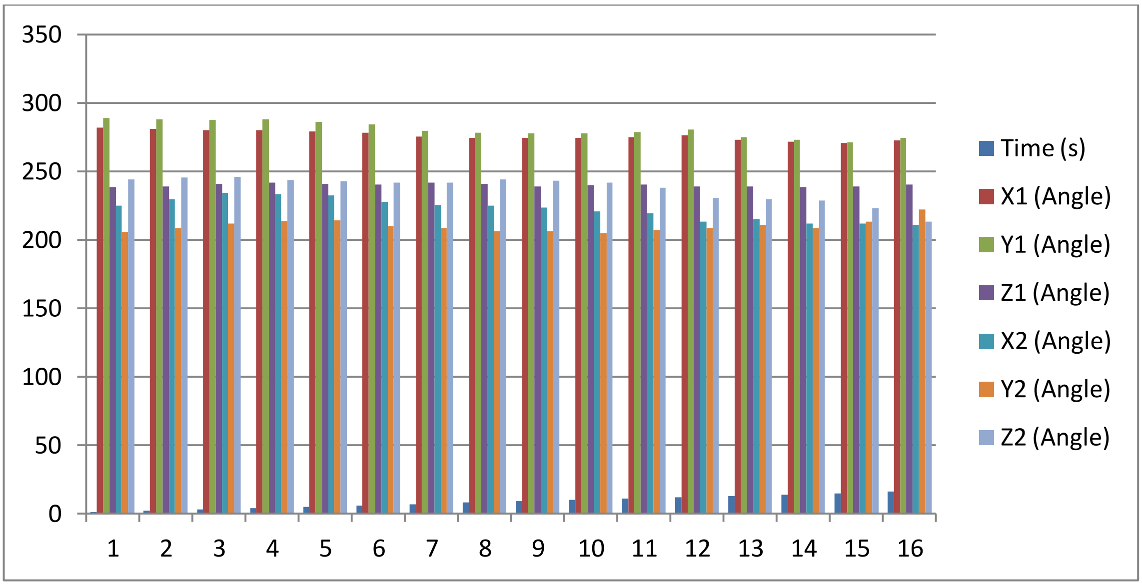

Figure 4.5: Graph standstill angular vs time

Table 4.2: Walking data

Time (s)	X1 (Angle)	Y1 (Angle)	Z1 (Angle)	X2 (Angle)	Y2 (Angle)	Z2 (Angle)
1	272.56	272.96	229.12	181.27	187.59	189.46
2	276.09	278.28	233.75	192.53	186.34	243.43
3	275	277.25	235.49	198.8	182.44	262.88
4	277.41	281.48	237.38	199.77	180.9	267.51
5	263.35	261.35	232.52	197.2	192.09	235.3
6	284.77	287.74	230.51	199.03	210.38	210.47
7	307.83	306.87	224.01	189.93	184.29	246.8
8	289.65	292.83	229.69	171.2	193.39	146.98
9	282.72	284.2	228.25	166.53	220.2	164.18
10	277.55	279.06	230.26	181.04	223.39	181.1
11	283.2	286.78	232.13	180	209.05	180
12	288	293.43	233.13	178.96	201.8	177.4
13	293.03	299.95	233.59	180	207.01	180
14	299.05	308.78	235.34	181.15	213.42	181.74
15	298	306.87	234.67	184.48	216.69	186.01
16	296.27	304.64	234.46	190.62	223.15	191.31

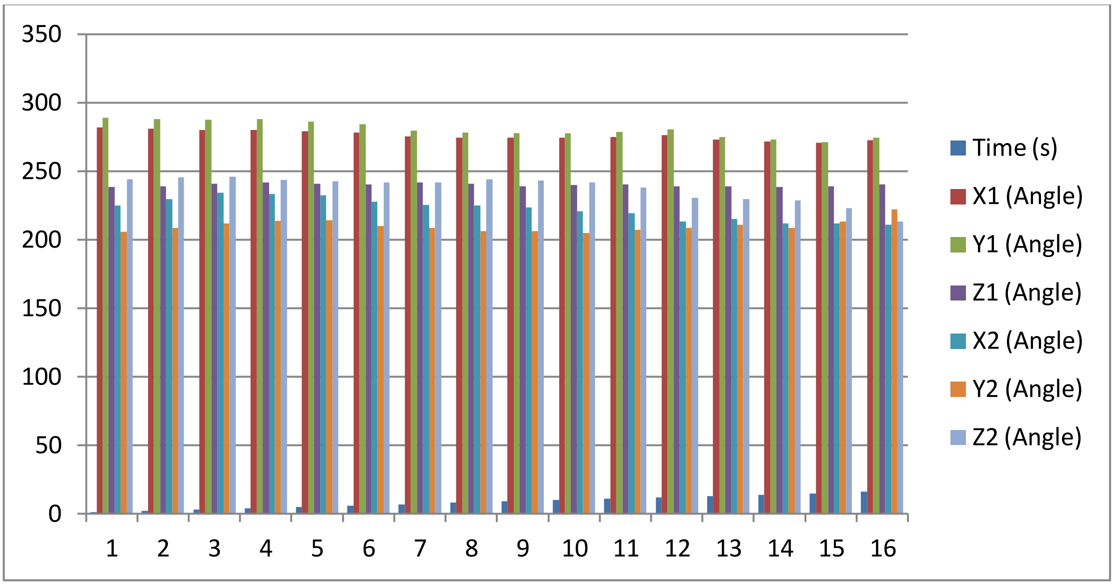

Figure 4.6: Graph walking angular vs time

Table 4.3: Running data

Time (s)	X1 (Angle)	Y1 (Angle)	Z1 (Angle)	X2 (Angle)	Y2 (Angle)	Z2 (Angle)
1	289.22	60.07	301.2	4.59	324.13	173.66
2	295.08	76.41	332.68	4.99	333.8	169.94
3	353.29	71.9	357.8	6.84	318.39	172.3
4	323.75	70.77	345.65	20.7	304.09	165.66
5	289.86	67.25	310.73	40.19	290.64	162.35
6	287.32	39.7	284.51	42.92	286.45	164.64
7	294.38	16.64	277.71	73.78	275.89	160.46
8	268.14	213.69	268.76	112.43	249.35	137.6
9	245.46	210.43	254.99	143.13	204.73	121.55
10	209.84	228.18	207.16	179.61	191.23	178.03
11	189.05	218.22	191.43	225.29	196.17	253.98
12	202.62	238.06	194.56	236.9	188.4	264.5
13	290.66	309.17	245.16	245.38	256.77	207.15
14	306.65	350.91	263.21	299.05	279.5	196.77
15	305.23	14.39	280.27	341.18	303.1	192.53
16	305.08	49.87	309.81	347.94	327.34	198.43

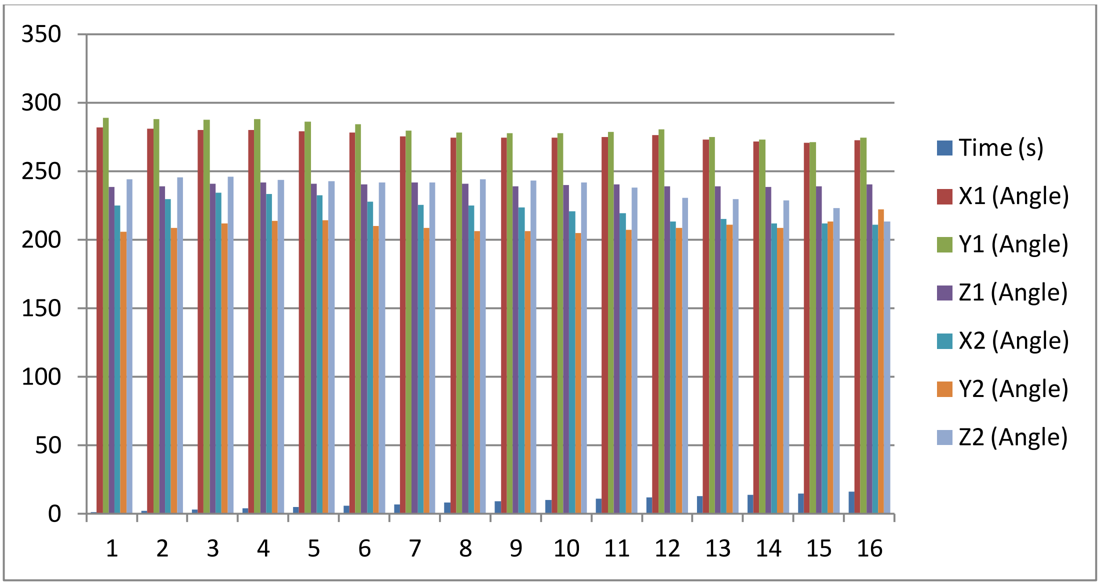

Figure 4.7: Graph running angular vs time

Table 4.4: Lifting data

Time (s)	X1 (Angle)	Y1 (Angle)	Z1 (Angle)	X2 (Angle)	Y2 (Angle)	Z2 (Angle)
1	274.82	278.47	240.48	192.53	225	192.53
2	282.89	289.38	236.95	182.54	217.87	183.27
3	277.46	282.41	239.24	187.43	229.57	186.34
4	275.84	281.07	242.4	189.87	220.29	191.59
5	273.37	275.6	239.04	190.62	219.09	192.99
6	270.66	271.04	237.7	184.86	216.67	186.52
7	270.71	271.25	240.41	194.62	230.09	192.31
8	274.6	278.65	242.13	181.27	225.63	181.25
9	274.82	277.82	238.43	202.31	223.49	203.39
10	275	278.84	240.64	210.53	209.43	226.27
11	276.5	284.83	246.71	205.71	250.44	189.71
12	275.78	281.04	242.57	180	234.87	180
13	268.68	267.8	239.13	185.6	216.69	187.5
14	264.29	259.99	240.46	191.69	207.35	201.8
15	267.4	265.84	237.99	193.35	214.8	198.85
16	271.95	272.86	235.71	201.8	210.11	214.59

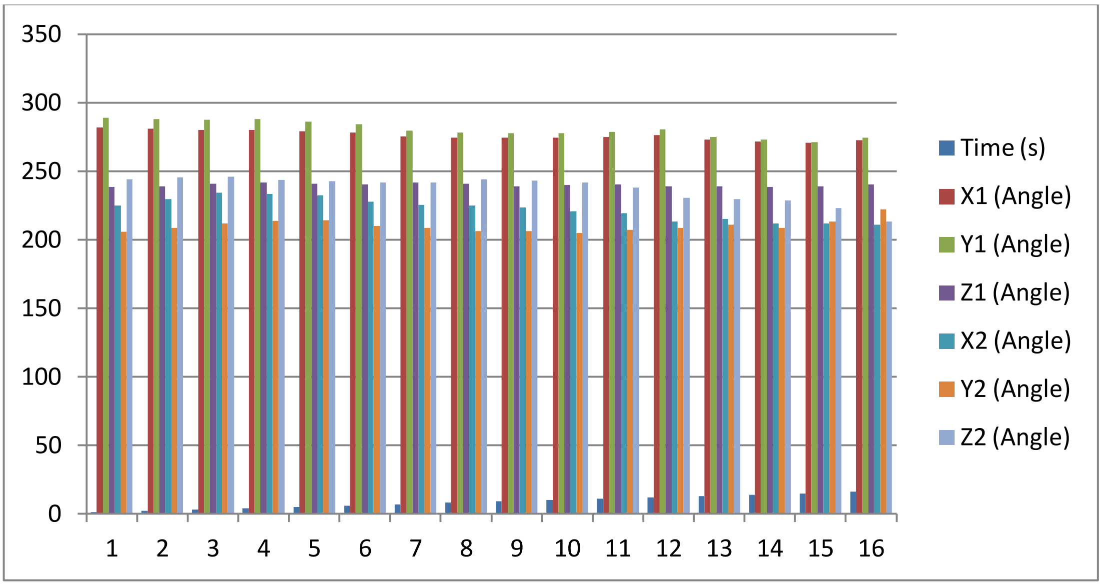

Figure 4.8: Graph lifting angular vs time

4.4 DATA SOURCE FROM OTHER PROJECT

From this project contains two data which are normal individual data and therapy patient data. In this project using accelerometer sensor located at arm and wrist.

4.4.1 MEASURED DATA OF NORMAL INDIVIDUAL

Table 4.5: Standstill data

Time (s)	X1 (Angle)	Y1 (Angle)	Z1 (Angle)	X2 (Angle)	Y2 (Angle)	Z2 (Angle)
1	278.22	283.07	238.11	201.8	214.99	209.74
2	278.31	283.07	237.82	201.8	214.99	209.74
3	280.19	285.95	237.82	200.56	215.31	207.9
4	280.08	285.95	238.11	199.8	214.99	207.22
5	279.36	285	238.39	202.38	214.46	210.96
6	277.59	281.69	237.2	202.38	215.96	209.58
7	278.31	282.63	236.91	202.38	214.46	210.96
8	280.19	285.95	237.82	202.78	214.22	211.7
9	280.58	286.34	237.49	202.38	213.69	211.7
10	279.97	285.42	237.49	202.78	213.42	212.47
11	279.57	285.26	238.28	203.63	212.86	214.11
12	279.57	285.26	238.28	203.63	214.51	212.47
13	280.19	285.95	237.82	201.8	214.22	210.47
14	280.08	285.95	238.11	201.41	213.69	210.47
15	280.19	285.95	237.82	201.8	214.22	210.47
16	280.7	286.89	238.11	202.78	214.22	211.7

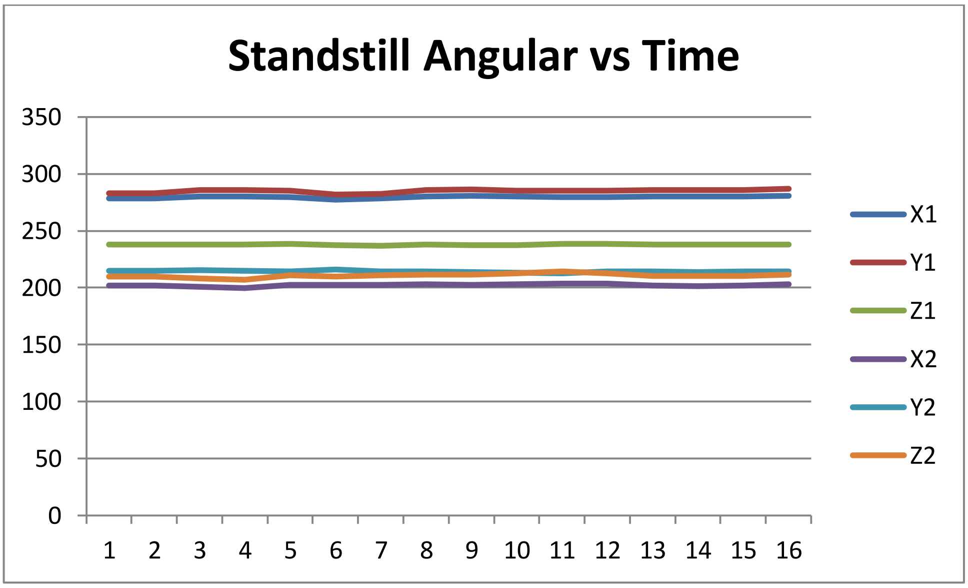

Figure 4.9: Graph standstill angular vs time

Table 4.6: Walking data

Time (s)	X1 (Angle)	Y1 (Angle)	Z1 (Angle)	X2 (Angle)	Y2 (Angle)	Z2 (Angle)
1	273.61	276.05	239.26	195.45	193.32	229.4
2	279.2	284.88	238.64	199.77	201.34	222.61
3	282.4	288.43	236.6	204.23	204.23	225
4	280.19	284.25	234.71	201.64	204.72	220.76
5	275.65	277.77	234.05	198.43	205.46	214.99
6	270.6	270.9	236.03	195.33	206.57	208.74
7	270.62	270.95	236.89	197.47	208.24	210.38
8	275.08	278.13	238.11	194.28	210.96	202.99
9	280.12	287.7	240.77	188.97	238.9	185.44
10	283.2	293.84	242.04	191.59	221.08	193.24
11	289.29	303.69	242.3	192.09	210.76	199.8
12	291.45	304.51	240.26	190.89	209.98	198.43
13	284.47	292.48	238.05	191.48	213.27	197.2
14	278.86	284.04	238.04	192.36	215.46	197.1
15	276.28	279.87	237.67	191.8	217.82	195.07
16	278.31	284.04	239.7	202.83	225.74	202.31

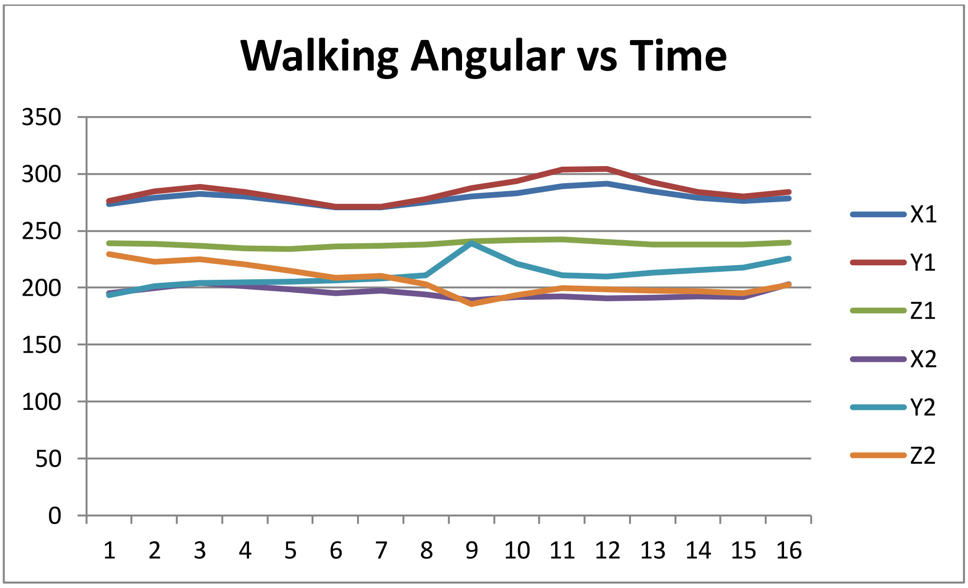

Figure 4.10: Graph walking angular vs time

Table 4.7: Running data

Time (s)	X1 (Angle)	Y1 (Angle)	Z1 (Angle)	X2 (Angle)	Y2 (Angle)	Z2 (Angle)
1	305.71	42.4	303.27	322.94	297.78	201.7
2	281.59	28.44	276.34	271.47	270.38	194.67
3	281	13.39	272.65	270	270	196.14
4	280.87	357.61	269.54	264.43	267.95	200.11
5	281.11	354.81	268.98	266.73	268.43	205.62
6	284.68	19.98	275.44	304.22	285.33	201.96
7	272.29	69.44	276.09	299.98	285.52	205.71
8	256.37	169.38	272.6	287.65	278.47	205.08
9	239.26	177.4	271.55	270	270	223.67
10	250.56	206.57	259.99	253.3	258.93	213.11
11	272.31	280.49	257.72	230.36	255.61	197.21
12	282.01	315	257.99	232.35	259.99	192.89
13	275.62	301.76	260.96	264.69	267.82	202.27
14	268.95	257.47	265.28	284.93	276.91	204.44
15	270	90	272.27	329.74	284.93	188.84
16	275.71	61.93	280.62	324.25	288.21	193.32

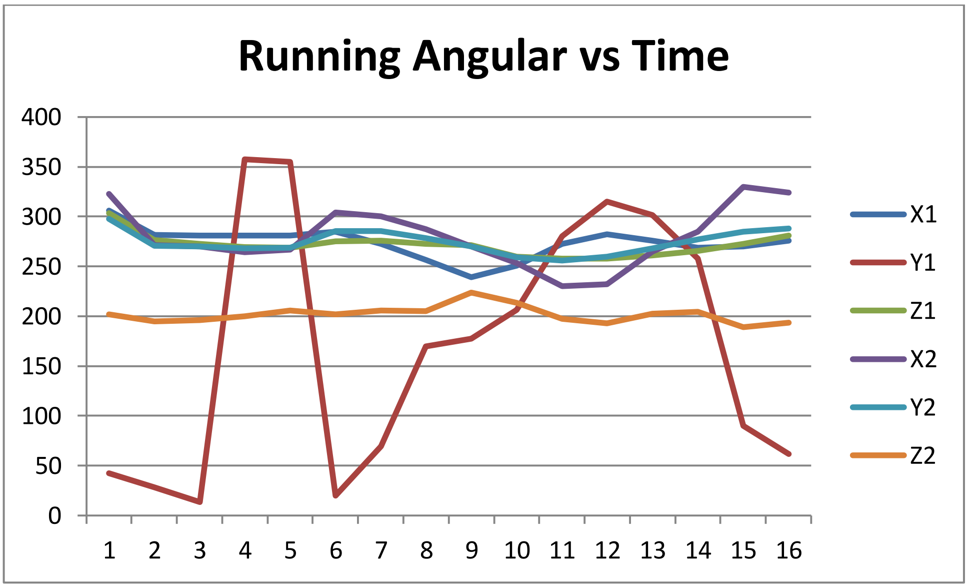

Figure 4.11: Graph running angular vs time

Table 4.8: Lifting data

Time (s)	X1 (Angle)	Y1 (Angle)	Z1 (Angle)	X2 (Angle)	Y2 (Angle)	Z2 (Angle)
1	294.98	37.97	289.98	329.26	290.49	192.53
2	284.85	57.09	292.28	333.92	295.4	193.08
3	282.53	69.15	300.26	332.65	300.11	196.7
4	291.25	60.26	304.24	337.25	300.56	193.91
5	298.72	52.96	305.98	341.57	305.36	193.31
6	302.81	46.15	303.86	337.31	304.18	195.85
7	305.98	41.57	302.77	339.83	303.87	193.85
8	300	52.28	306.74	343.61	310.36	194.04
9	295.8	62.2	312.51	345.75	315	194.25
10	301.26	59.62	316.01	342.1	315.44	198.17
11	313.85	52.13	321.01	345.62	321.07	197.61
12	320.01	45	320.01	344.96	323.27	199.8
13	318.12	48.26	321.34	344.27	320.75	199.03
14	318.37	51.13	324.38	348.69	324.06	195.42
15	320.49	50.03	325.35	349.95	327.15	195.35
16	327.53	47.49	329.74	350.31	330.71	196.93

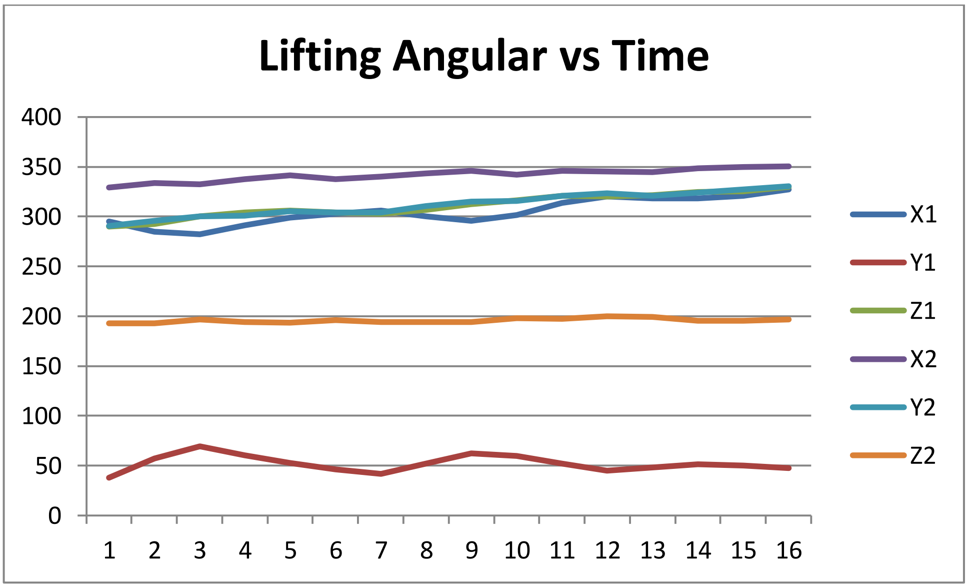

Figure 4.12: Graph lifting angular vs time

4.4.2 MEASURED DATA OF THERAPY PATIENT

Table 4.9: Standstill data

Time (s)	X1 (Angle)	Y1 (Angle)	Z1 (Angle)	X2 (Angle)	Y2 (Angle)	Z2 (Angle)
1	270.67	271.15	239.53	216.47	210.41	231.55
2	268.7	267.75	239.91	214.99	207.47	233.39
3	266.78	264.81	238.28	217.87	186.34	261.87
4	268.74	267.95	238.39	219.91	172.75	278.65
5	270	270	238.85	218.93	189.82	257.91
6	271.95	273.18	238.47	217.23	194.57	251.11
7	271.97	273.3	239.13	218.96	204.08	241.07
8	270	270	239.42	220.5	200.56	246.3
9	272.69	274.48	239.04	221.71	196.93	251.15
10	276.12	280.2	239.24	223.64	201.57	247.48
11	277.21	282.41	240.11	221.71	204.54	242.88
12	275.65	279.82	240.26	219.47	202.38	243.43
13	274.3	277.13	238.95	219.81	201.25	244.98
14	272.52	274.16	238.85	223.78	200.56	248.63
15	275.25	278.91	239.62	223.07	196.93	251.97
16	277.21	282.17	239.62	223.07	199.18	249.59

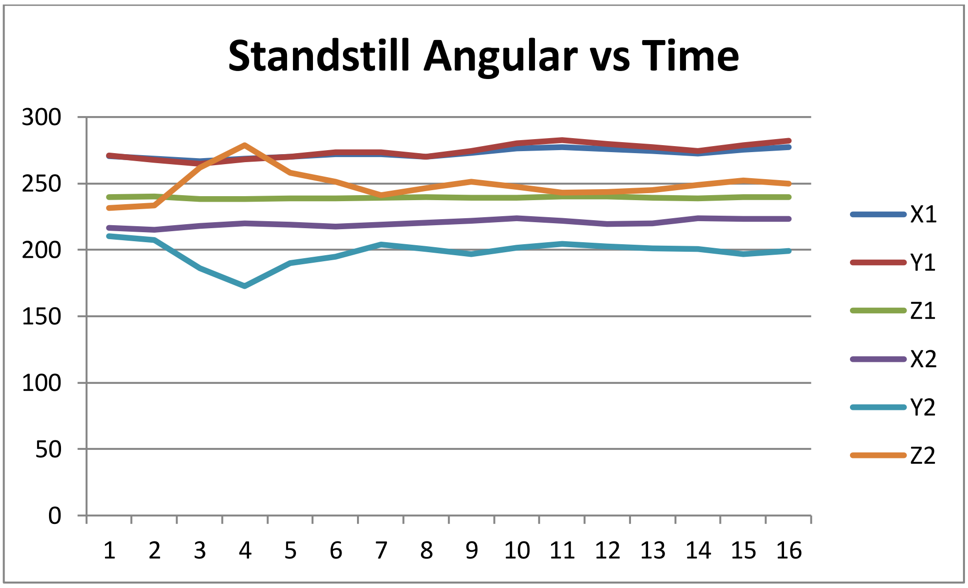

Figure 4.13: Graph standstill angular vs time

Table 4.10: Walking data

Time (s)	X1 (Angle)	Y1 (Angle)	Z1 (Angle)	X2 (Angle)	Y2 (Angle)	Z2 (Angle)
1	281.92	289.06	238.57	225	205.74	244.26
2	281.08	288.14	239.12	229.72	208.37	245.41
3	279.97	287.42	240.73	234.09	211.76	245.85
4	280.01	288.06	241.58	233.13	213.69	243.43
5	279.12	286.11	240.95	232.37	214.05	242.49
6	278.23	284.32	240.48	227.54	210.17	241.99
7	275.25	279.66	241.62	225.62	208.52	241.99
8	274.5	277.97	240.67	225	206.08	243.92
9	274.6	277.67	239.13	223.75	206.08	242.93
10	274.45	277.67	239.98	220.7	204.7	241.86
11	274.97	278.75	240.52	219.47	207.01	238.24
12	276.28	280.39	239.04	213.48	208.74	230.33
13	272.86	274.76	239.04	215.26	211.11	229.51
14	271.77	272.91	238.69	211.72	208.61	228.58
15	270.62	271.04	239.13	211.8	213.42	223.21
16	272.57	274.48	240.19	210.96	222.34	213.37

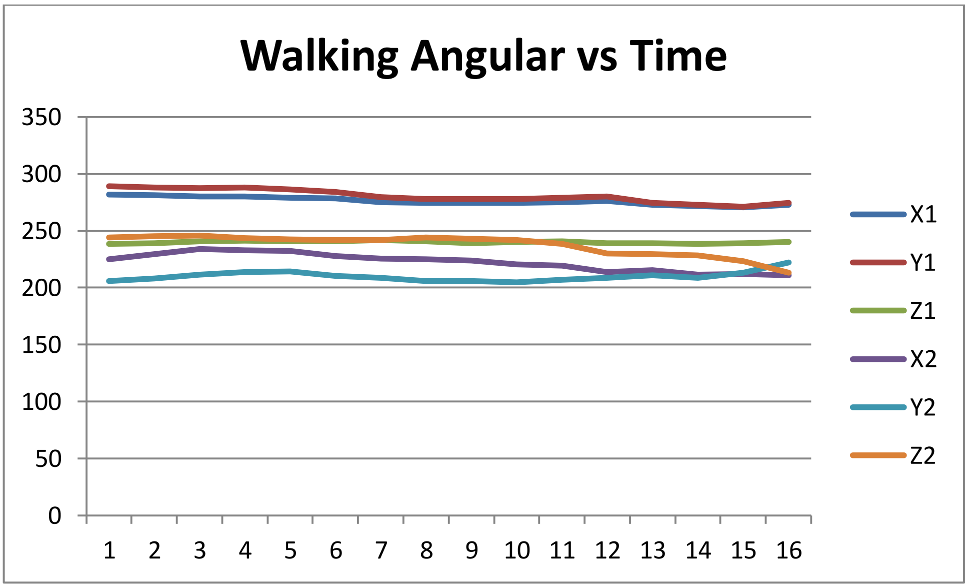

Figure 4.14: Graph walking angular vs time

Table 4.11: Running data

Time (s)	X1 (Angle)	Y1 (Angle)	Z1 (Angle)	X2 (Angle)	Y2 (Angle)	Z2 (Angle)
1	281.92	289.06	238.57	225	205.74	244.26
2	281.08	288.14	239.12	229.72	208.37	245.41
3	279.97	287.42	240.73	234.09	211.76	245.85
4	280.01	288.06	241.58	233.13	213.69	243.43
5	279.12	286.11	240.95	232.37	214.05	242.49
6	278.23	284.32	240.48	227.54	210.17	241.99
7	275.25	279.66	241.62	225.62	208.52	241.99
8	274.5	277.97	240.67	225	206.08	243.92
9	274.6	277.67	239.13	223.75	206.08	242.93
10	274.45	277.67	239.98	220.7	204.7	241.86
11	274.97	278.75	240.52	219.47	207.01	238.24
12	276.28	280.39	239.04	213.48	208.74	230.33
13	272.86	274.76	239.04	215.26	211.11	229.51
14	271.77	272.91	238.69	211.72	208.61	228.58
15	270.62	271.04	239.13	211.8	213.42	223.21
16	272.57	274.48	240.19	210.96	222.34	213.37

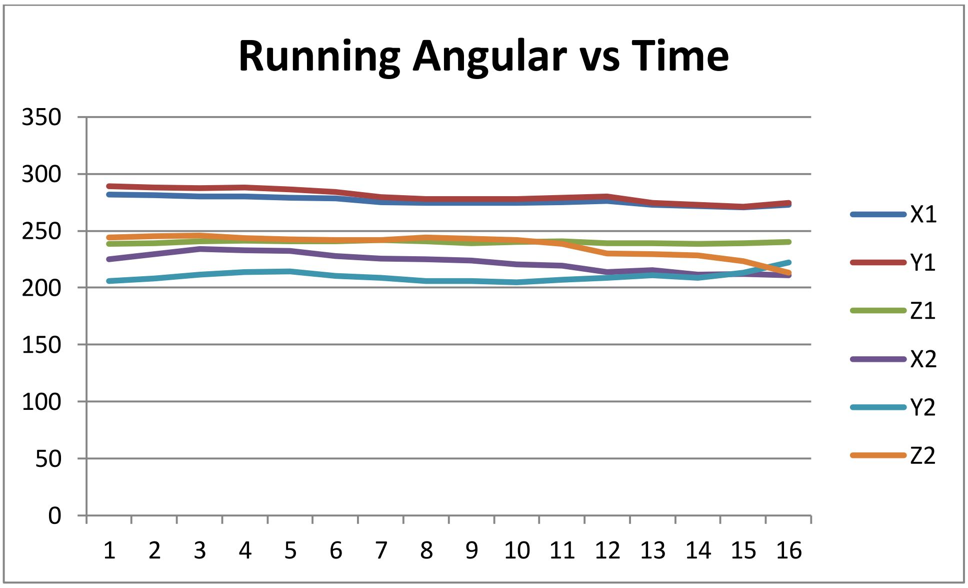

Figure 4.15: Graph running angular vs time

Table 4.12: Lifting data

Time (s)	X1 (Angle)	Y1 (Angle)	Z1 (Angle)	X2 (Angle)	Y2 (Angle)	Z2 (Angle)
1	281.92	289.06	238.57	225	205.74	244.26
2	281.08	288.14	239.12	229.72	208.37	245.41
3	279.97	287.42	240.73	234.09	211.76	245.85
4	280.01	288.06	241.58	233.13	213.69	243.43
5	279.12	286.11	240.95	232.37	214.05	242.49
6	278.23	284.32	240.48	227.54	210.17	241.99
7	275.25	279.66	241.62	225.62	208.52	241.99
8	274.5	277.97	240.67	225	206.08	243.92
9	274.6	277.67	239.13	223.75	206.08	242.93
10	274.45	277.67	239.98	220.7	204.7	241.86
11	274.97	278.75	240.52	219.47	207.01	238.24
12	276.28	280.39	239.04	213.48	208.74	230.33
13	272.86	274.76	239.04	215.26	211.11	229.51
14	271.77	272.91	238.69	211.72	208.61	228.58
15	270.62	271.04	239.13	211.8	213.42	223.21
16	272.57	274.48	240.19	210.96	222.34	213.37

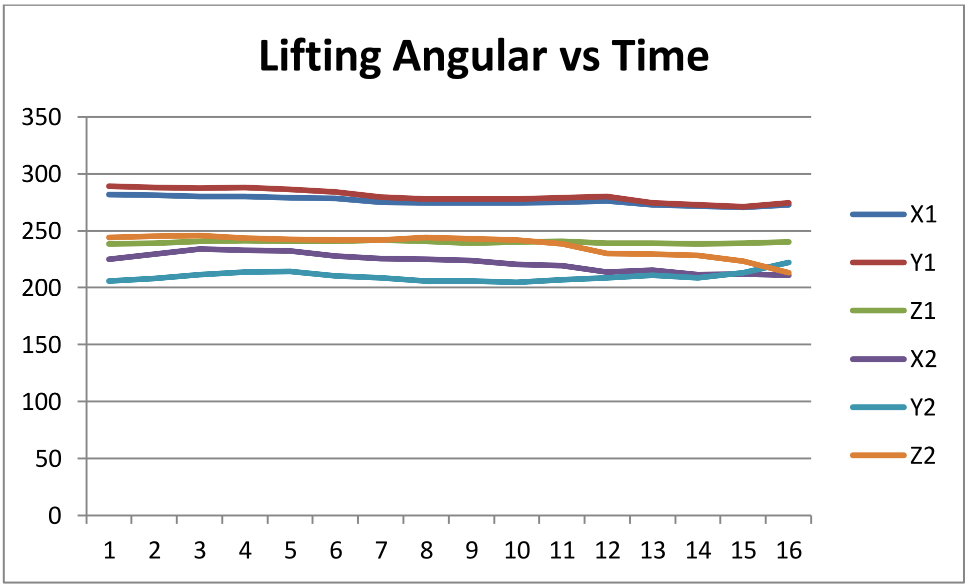

Figure 4.16: Graph lifting angular vs time

4.5 RESULTS

4.5.1 SUBJECT 1st

Table 4.13: Standstill Data

Wrist			Shoulder		
X1	Y1	Z1	X2	Y2	Z2
90.38	0.38	90.00	94.64	4.64	90.00
90.38	0.38	90.00	94.63	4.63	90.00
90.38	0.38	90.00	94.61	4.61	90.00
90.38	0.38	90.00	94.58	4.58	90.00
90.38	0.38	90.00	94.55	4.55	90.00
90.38	0.38	90.00	94.52	4.52	90.00
90.38	0.38	90.00	94.48	4.48	90.00
90.38	0.38	90.00	94.44	4.44	90.00
90.38	0.38	90.00	94.39	4.39	90.00
90.37	0.37	90.00	94.34	4.34	90.00

90.37	0.37	90.00	94.28	4.28	90.00
90.37	0.37	90.00	94.23	4.23	90.00
90.37	0.37	90.00	94.17	4.17	90.00
90.37	0.37	90.00	94.10	4.10	90.00
90.35	0.35	90.00	94.04	4.04	90.00

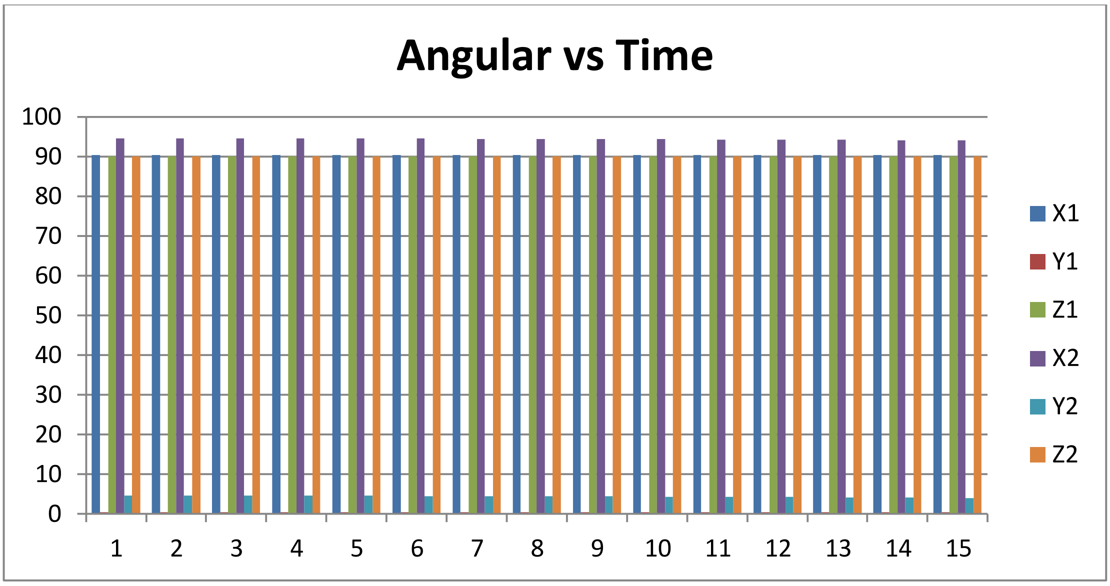

Figure 4.17: Graph standstill angular vs time

Table 4.14: Walking Data

Wrist			Shoulder		
X1	Y1	Z1	X2	Y2	Z2
90.89	0.89	90.00	91.88	1.88	90.00
90.89	0.89	90.00	91.90	1.90	90.00
90.89	0.89	90.00	91.92	1.92	90.00
90.89	0.89	90.00	91.93	1.93	90.00
90.91	0.91	90.00	91.95	1.95	90.00
90.91	0.91	90.00	91.97	1.97	90.00

90.91	0.91	90.00	91.98	1.98	90.00
90.92	0.92	90.00	92.00	2.00	90.00
90.92	0.92	90.00	92.01	2.01	90.00
90.92	0.92	90.00	92.02	2.02	90.00
90.92	0.92	90.00	92.03	2.03	90.00
90.92	0.92	90.00	92.04	2.04	90.00
90.94	0.94	90.00	92.05	2.05	90.00
90.94	0.94	90.00	92.06	2.06	90.00
90.94	0.94	90.00	92.06	2.06	90.00

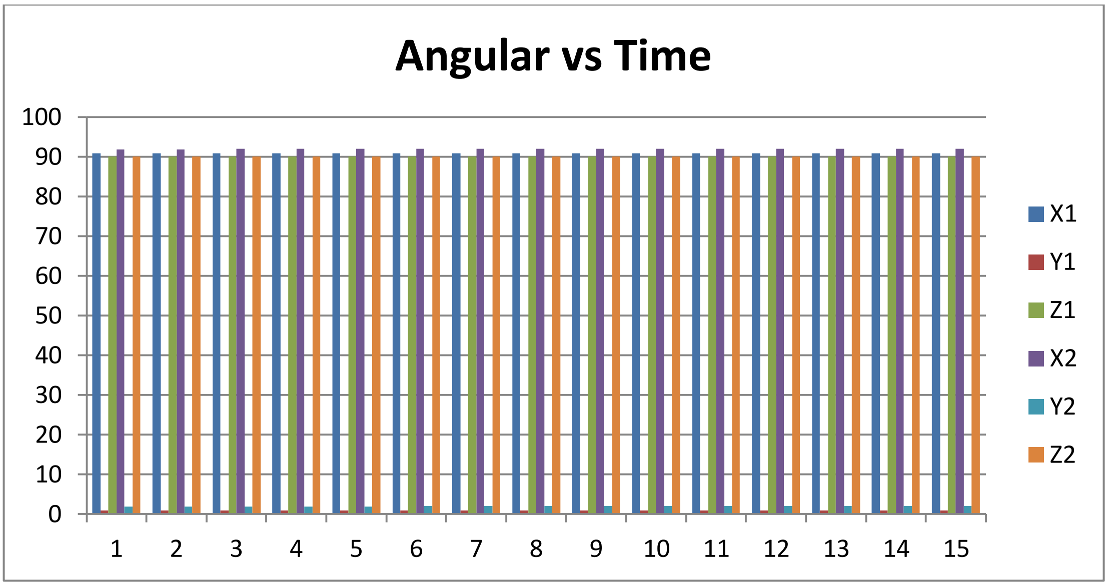

Figure 4.18: Graph walking angular vs time

Table 4.15: Running Data

Wrist			Shoulder		
X1	Y1	Z1	X2	Y2	Z2
88.55	1.45	90.00	92.75	2.75	90.00
88.60	1.40	90.00	92.11	2.11	90.00

88.63	1.37	90.00	91.43	1.43	90.00
88.65	1.35	90.00	90.71	0.71	90.00
88.66	1.34	90.00	89.94	0.06	90.00
88.65	1.35	90.00	89.10	0.90	90.00
88.63	1.37	90.00	88.22	1.78	90.00
88.61	1.39	90.00	87.35	2.65	90.00
88.57	1.43	90.00	86.48	3.52	90.00
88.52	1.48	90.00	85.63	4.37	90.00
88.47	1.53	90.00	84.82	5.18	90.00
88.41	1.59	90.00	84.06	5.94	90.00
88.34	1.66	90.00	83.39	6.61	90.00
88.30	1.70	90.00	82.80	7.20	90.00
88.25	1.75	90.00	82.30	7.70	90.00

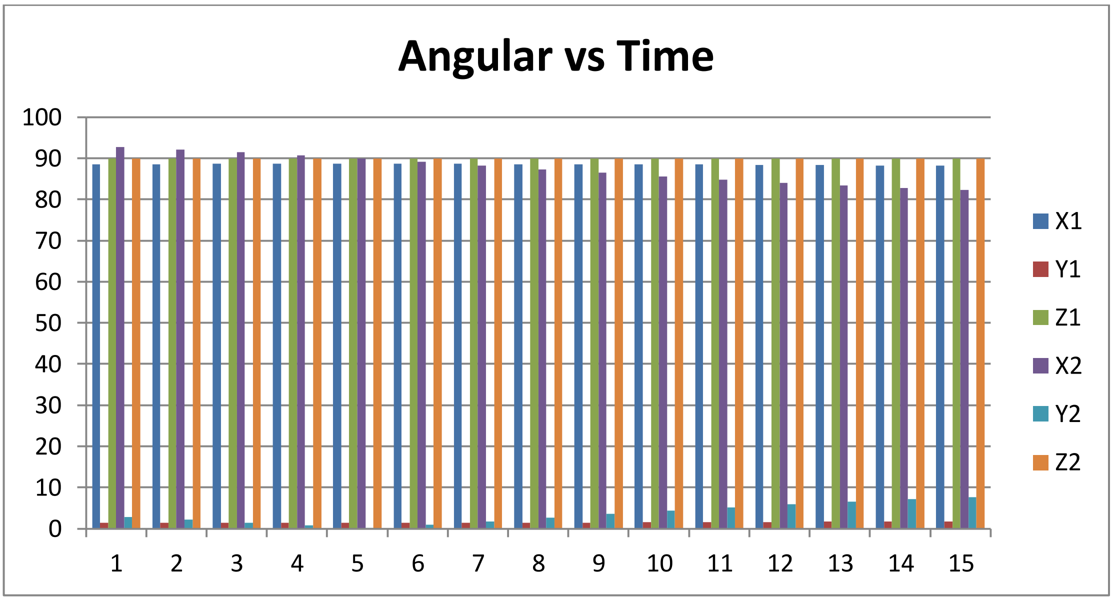

Figure 4.19: Graph running angular vs time

Table 4.16: Lifting Data

Wrist			Shoulder		
X1	Y1	Z1	X2	Y2	Z2
88.90	1.10	90.00	44.87	45.13	90.00
88.90	1.10	90.00	44.92	45.08	90.00
88.90	1.10	90.00	44.98	45.02	90.00
88.90	1.10	90.00	45.02	44.98	90.00
88.90	1.10	90.00	45.06	44.94	90.00
88.90	1.10	90.00	45.10	44.90	90.00
88.90	1.10	90.00	45.13	44.87	90.00
88.92	1.08	90.00	45.17	44.83	90.00
88.92	1.08	90.00	45.19	44.81	90.00
88.92	1.08	90.00	45.21	44.79	90.00
88.92	1.08	90.00	45.23	44.77	90.00
88.92	1.08	90.00	45.24	44.76	90.00
88.92	1.08	90.00	45.25	44.75	90.00
88.92	1.08	90.00	45.25	44.75	90.00
88.93	1.07	90.00	45.25	44.75	90.00

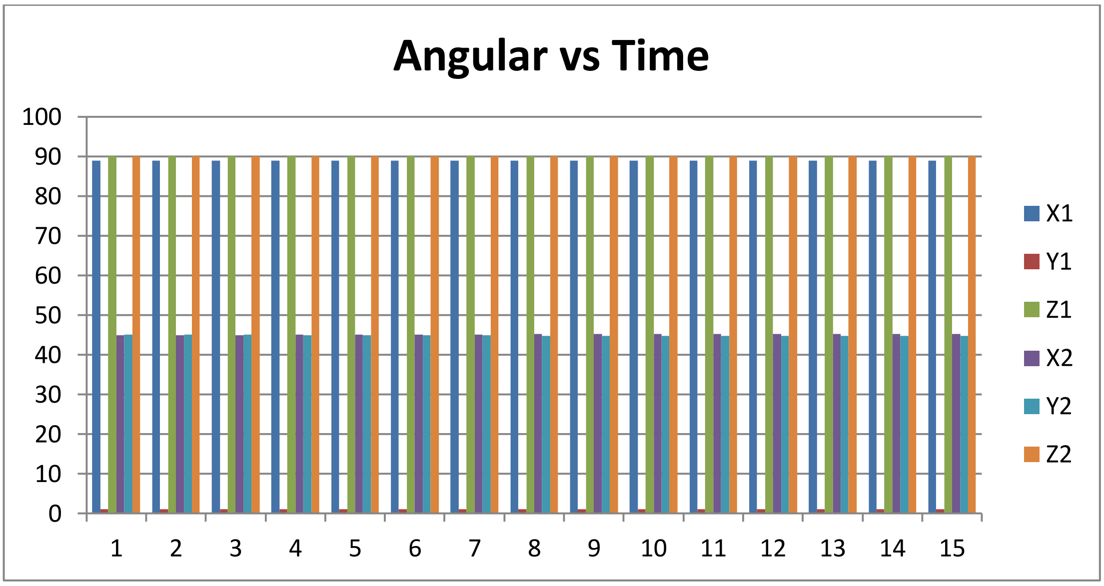

Figure 4.20: Graph lifting angular vs time

4.5.2 SUBJECT 2nd

Table 4.17: Standstill Data

Wrist			Shoulder		
X1	Y1	Z1	X2	Y2	Z2
90.35	0.35	90.00	93.97	3.97	90.00
90.35	0.35	90.00	93.91	3.91	90.00
90.35	0.35	90.00	93.86	3.86	90.00
90.33	0.33	90.00	93.80	3.80	90.00
90.33	0.33	90.00	93.74	3.74	90.00
90.33	0.33	90.00	93.68	3.68	90.00
90.32	0.32	90.00	93.63	3.63	90.00
90.32	0.32	90.00	93.57	3.57	90.00
90.32	0.32	90.00	93.53	3.53	90.00
90.32	0.32	90.00	93.48	3.48	90.00
90.30	0.30	90.00	93.44	3.44	90.00

90.30	0.30	90.00	93.41	3.41	90.00
90.30	0.30	90.00	93.37	3.37	90.00
90.30	0.30	90.00	93.34	3.34	90.00
90.29	0.29	90.00	93.32	3.32	90.00

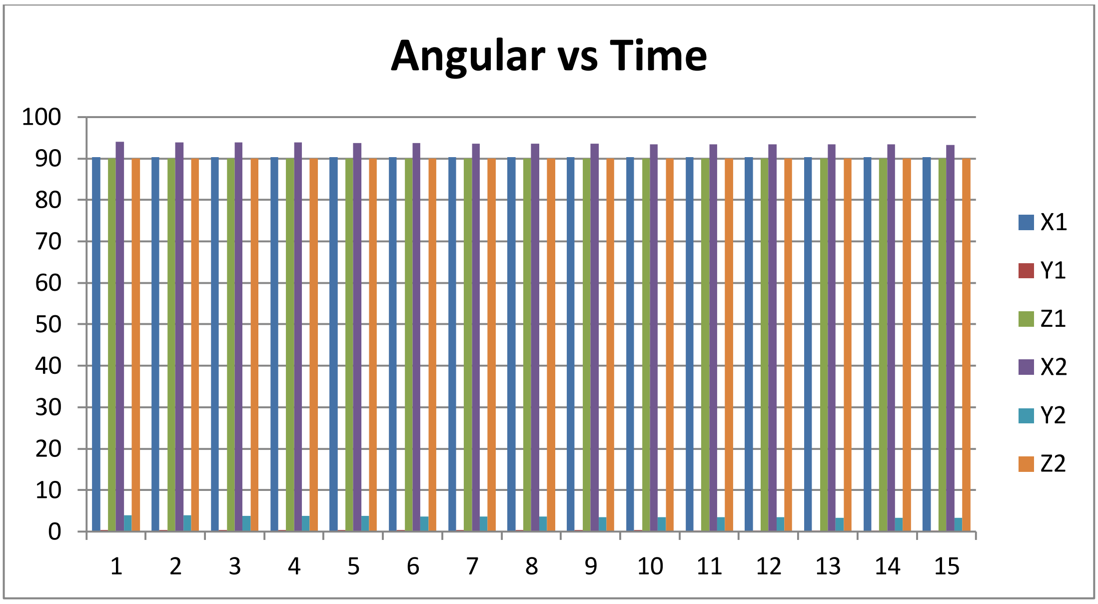

Figure 4.21: Graph standstill angular vs time

Table 4.18: Walking Data

Wrist			Shoulder		
X1	Y1	Z1	X2	Y2	Z2
90.94	0.94	90.00	92.07	2.07	90.00
90.94	0.94	90.00	92.08	2.08	90.00
90.94	0.94	90.00	92.09	2.09	90.00
90.96	0.96	90.00	92.10	2.10	90.00
90.96	0.96	90.00	92.10	2.10	90.00
90.96	0.96	90.00	92.11	2.11	90.00
90.96	0.96	90.00	92.11	2.11	90.00

90.96	0.96	90.00	92.11	2.11	90.00
90.96	0.96	90.00	92.11	2.11	90.00
90.96	0.96	90.00	92.10	2.10	90.00
90.96	0.96	90.00	92.10	2.10	90.00
90.96	0.96	90.00	92.09	2.09	90.00
90.96	0.96	90.00	92.09	2.09	90.00
90.96	0.96	90.00	92.08	2.08	90.00
90.96	0.96	90.00	92.07	2.07	90.00

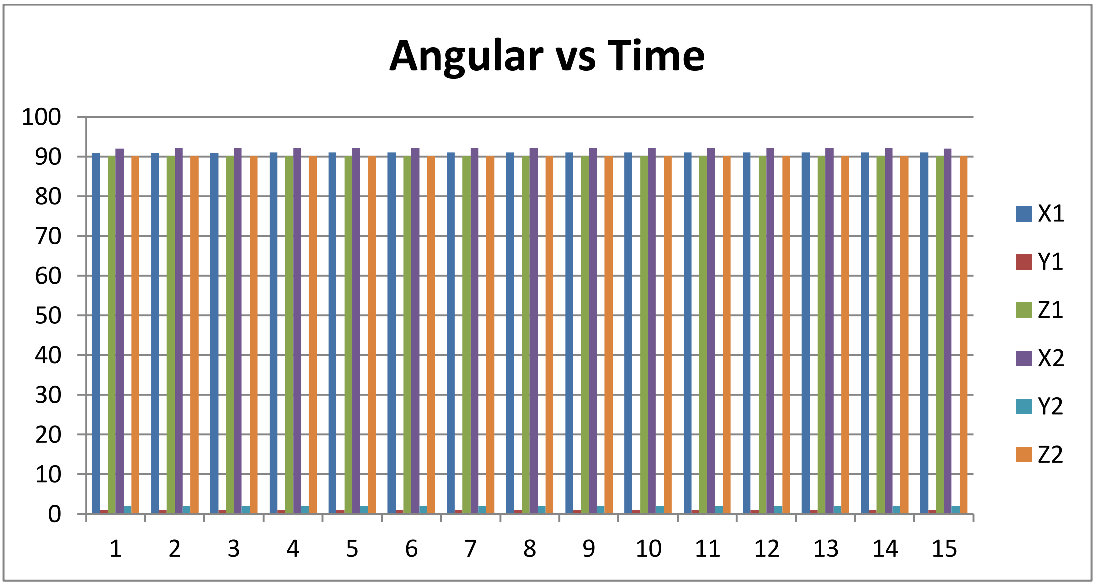

Figure 4.22: Graph walking angular vs time

Table 4.19: Running Data

Wrist			Shoulder		
X1	Y1	Z1	X2	Y2	Z2
88.18	1.82	90.00	81.85	8.15	90.00
88.14	1.86	90.00	81.46	8.54	90.00
88.09	1.91	90.00	81.11	8.89	90.00

88.06	1.94	90.00	80.81	9.19	90.00
88.01	1.99	90.00	80.55	9.45	90.00
87.98	2.02	90.00	80.31	9.69	90.00
87.95	2.05	90.00	80.13	9.87	90.00
87.93	2.07	90.00	80.00	10.00	90.00
87.91	2.09	90.00	79.93	10.07	90.00
87.90	2.10	90.00	79.94	10.06	90.00
87.90	2.10	90.00	80.02	9.98	90.00
87.90	2.10	90.00	80.15	9.85	90.00
87.90	2.10	90.00	80.31	9.69	90.00
87.88	2.12	90.00	80.48	9.52	90.00
87.88	2.12	90.00	80.66	9.34	90.00

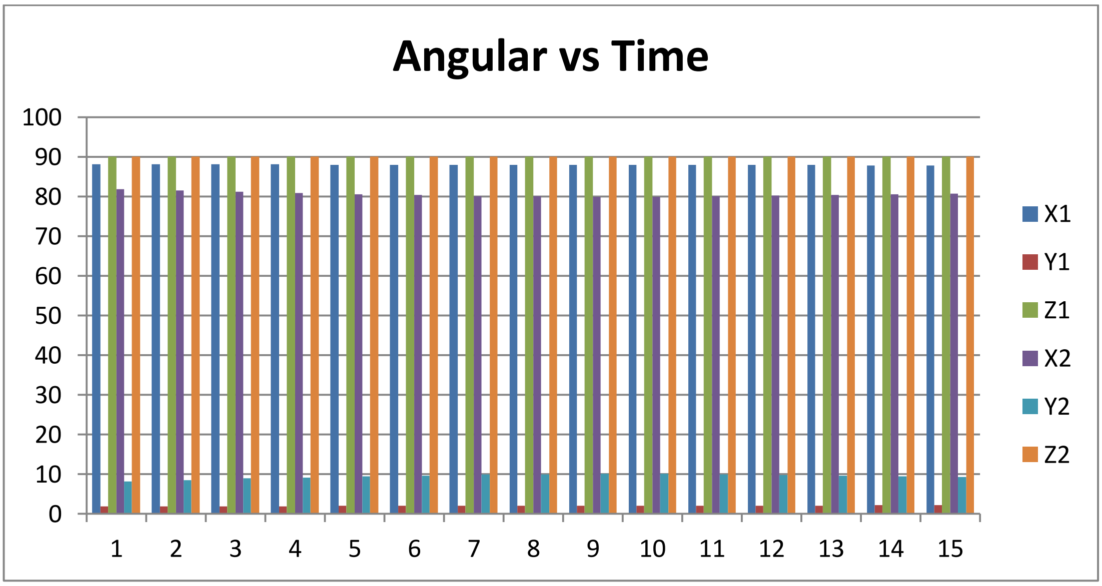

Figure 4.23: Graph running angular vs time

Table 4.20: Lifting Data

Wrist			Shoulder		
X1	Y1	Z1	X2	Y2	Z2
88.93	1.07	90.00	45.24	44.76	90.00
88.93	1.07	90.00	45.24	44.76	90.00
88.93	1.07	90.00	45.23	44.77	90.00
88.93	1.07	90.00	45.22	44.78	90.00
88.95	1.05	90.00	45.20	44.80	90.00
88.95	1.05	90.00	45.19	44.81	90.00
88.95	1.05	90.00	45.17	44.83	90.00
88.95	1.05	90.00	45.15	44.85	90.00
88.97	1.03	90.00	45.13	44.87	90.00
88.97	1.03	90.00	45.11	44.89	90.00
88.97	1.03	90.00	45.09	44.91	90.00
88.97	1.03	90.00	45.06	44.94	90.00
88.98	1.02	90.00	45.02	44.98	90.00
88.98	1.02	90.00	44.99	45.01	90.00
88.98	1.02	90.00	44.96	45.04	90.00

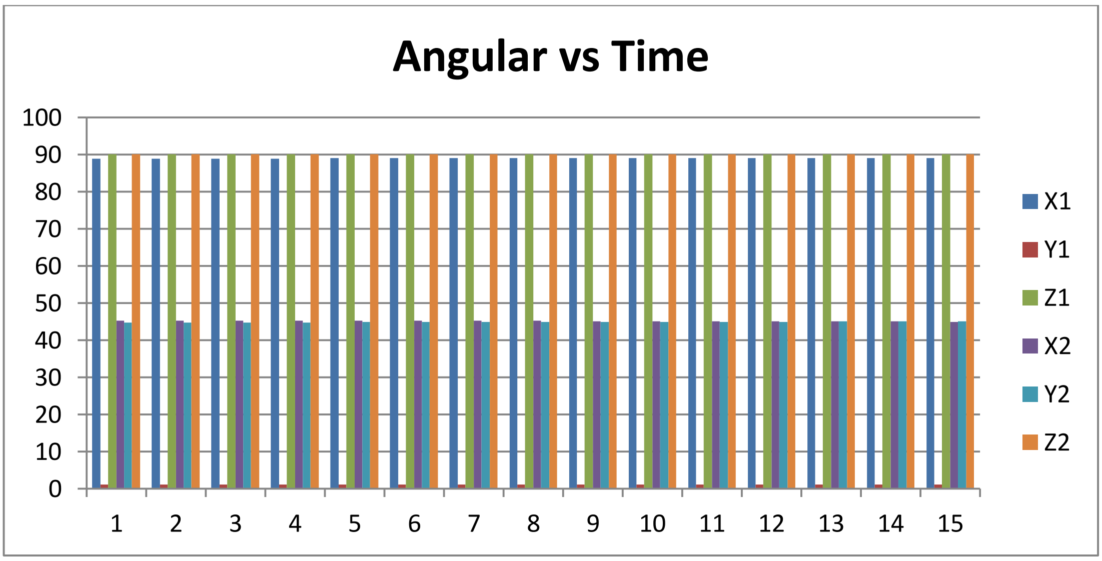

Figure 4.24: Graph lifting angular vs time

4.5.3 SUBJECT 3rd

Table 4.21: Standstill Data

Wrist			Shoulder		
X1	Y1	Z1	X2	Y2	Z2
90.29	0.29	90.00	93.29	3.29	90.00
90.29	0.29	90.00	93.27	3.27	90.00
90.29	0.29	90.00	93.26	3.26	90.00
90.29	0.29	90.00	93.24	3.24	90.00
90.27	0.27	90.00	93.22	3.22	90.00
90.27	0.27	90.00	93.21	3.21	90.00
90.27	0.27	90.00	93.20	3.20	90.00
90.27	0.27	90.00	93.18	3.18	90.00
90.25	0.25	90.00	93.17	3.17	90.00
90.25	0.25	90.00	93.16	3.16	90.00
90.25	0.25	90.00	93.14	3.14	90.00
90.25	0.25	90.00	93.13	3.13	90.00
90.25	0.25	90.00	93.12	3.12	90.00
90.24	0.24	90.00	93.11	3.11	90.00
90.24	0.24	90.00	93.10	3.10	90.00

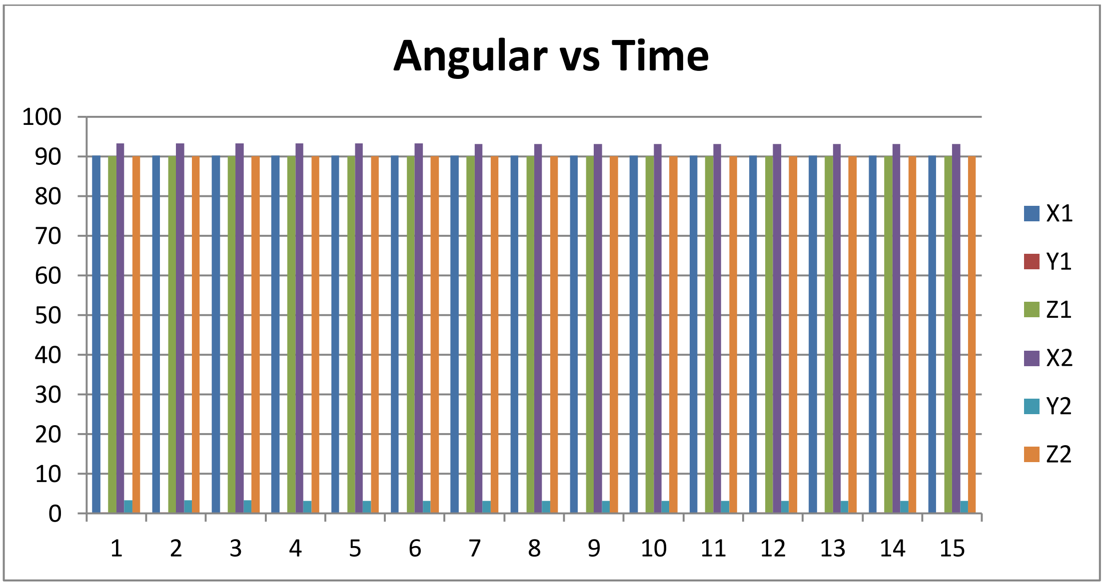

Figure 4.25: Graph standstill angular vs time

Table 4.22: Walking Data

Wrist			Shoulder		
X1	Y1	Z1	X2	Y2	Z2
90.96	0.96	90.00	92.06	2.06	90.00
90.89	0.89	90.00	91.78	1.78	90.00
90.84	0.84	90.00	91.61	1.61	90.00
90.80	0.80	90.00	91.44	1.44	90.00
90.75	0.75	90.00	91.26	1.26	90.00
90.70	0.70	90.00	91.09	1.09	90.00
90.67	0.67	90.00	90.91	0.91	90.00
90.62	0.62	90.00	90.73	0.73	90.00
90.57	0.57	90.00	90.54	0.54	90.00
90.54	0.54	90.00	90.34	0.34	90.00
90.49	0.49	90.00	90.14	0.14	90.00
90.45	0.45	90.00	89.95	0.05	90.00
90.41	0.41	90.00	89.76	0.24	90.00
90.37	0.37	90.00	89.58	0.42	90.00

90.32	0.32	90.00	89.39	0.61	90.00

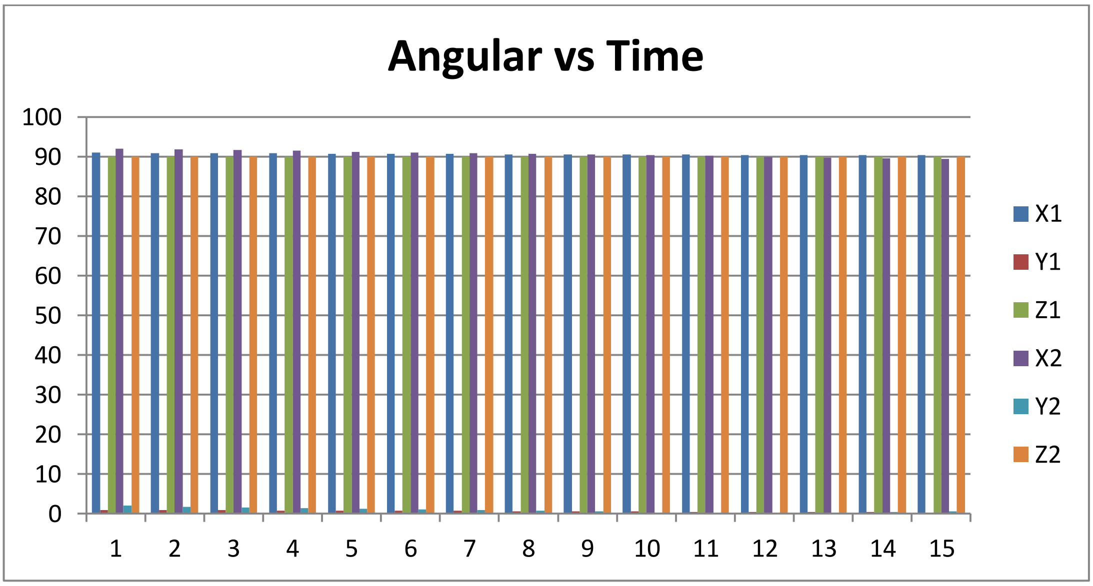

Figure 4.26: Graph walkingl angular vs time

Table 4.23: Running Data

Wrist			Shoulder		
X1	Y1	Z1	X2	Y2	Z2
87.79	2.21	90.00	81.18	7.82	90.00
87.79	2.21	90.00	81.96	8.04	90.00
87.77	2.23	90.00	81.72	8.28	90.00
87.77	2.23	90.00	81.44	8.56	90.00
87.75	2.25	90.00	81.10	8.90	90.00
87.74	2.26	90.00	80.73	9.27	90.00
87.71	2.29	90.00	80.33	9.67	90.00
87.67	2.33	90.00	79.92	10.08	90.00
87.66	2.34	90.00	79.50	10.50	90.00
87.63	2.37	90.00	79.08	10.92	90.00

87.59	2.41	90.00	78.66	11.34	90.00
87.56	2.44	90.00	78.25	11.75	90.00
87.51	2.49	90.00	77.84	12.57	90.00
87.48	2.52	90.00	77.43	12.66	90.00
87.45	2.55	90.00	77.02	12.98	90.00

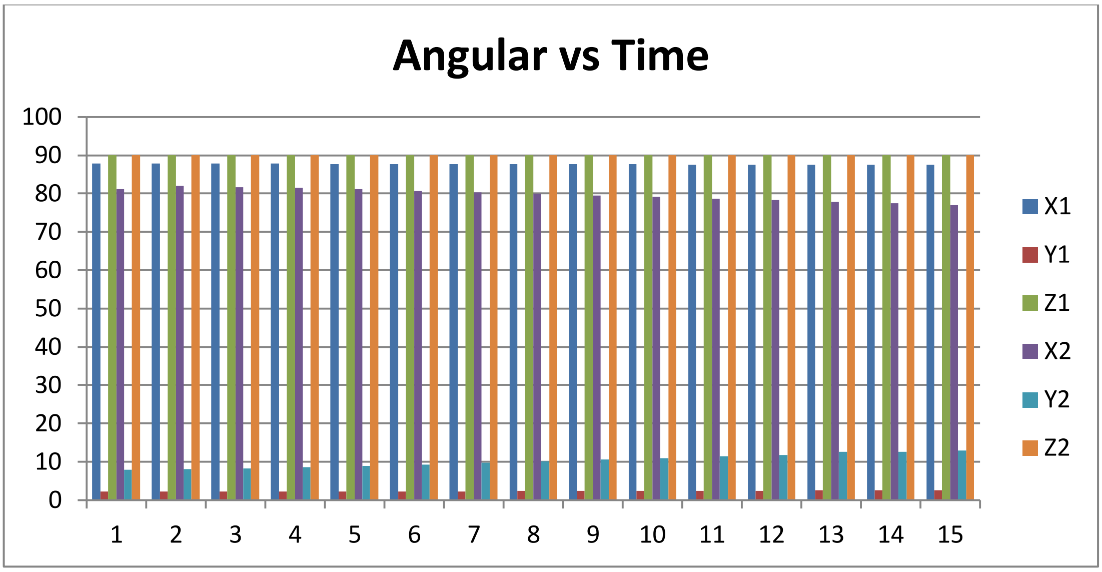

Figure 4.27: Graph running angular vs time

Table 4.24: Lifting Data

Wrist			Shoulder		
X1	Y1	Z1	X2	Y2	Z2
89.00	1.00	90.00	44.93	45.07	90.00
89.00	1.00	90.00	44.90	45.10	90.00
89.00	1.00	90.00	44.86	45.14	90.00
89.01	0.99	90.00	44.83	45.17	90.00
89.01	0.99	90.00	44.79	45.21	90.00
89.01	0.99	90.00	44.74	45.26	90.00

89.03	0.97	90.00	44.69	45.31	90.00
89.03	0.97	90.00	44.64	45.36	90.00
89.03	0.97	90.00	44.59	45.41	90.00
89.04	0.96	90.00	44.52	45.48	90.00
89.04	0.96	90.00	44.45	45.55	90.00
89.04	0.96	90.00	44.38	45.62	90.00
89.06	0.94	90.00	44.30	45.70	90.00
89.06	0.94	90.00	44.21	45.79	90.00
89.08	0.92	90.00	44.11	45.89	90.00

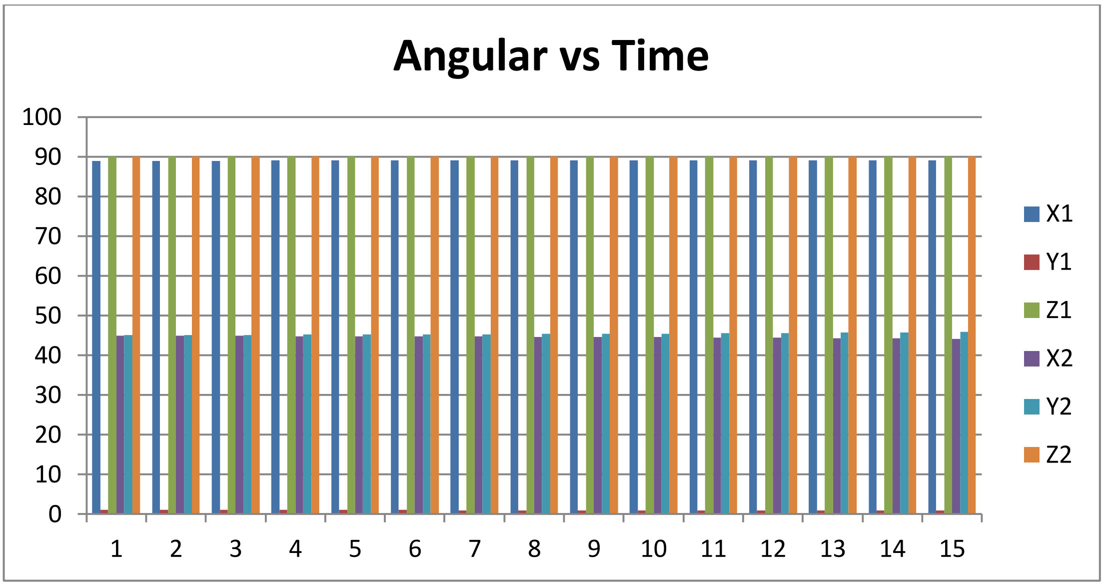

Figure 4.28: Graph lifting angular vs time

4.6 DISCUSSION

Shapetape sensor is suitable for detecting the movement. Based on the results obtained, there are changes the values of x-axis and y-axis but for the zaxis maintained. The value will change from time to time based on the subject make the movement. The angular values must in range from 0 to 360 degree.

Based on the tables and figures shown above, the are three results is dispayed which are source data from journal, data from other project, followed by thid project results. Then all this results can be compare using error percentage formula to determine the similarity.

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$$

Figure 4.27: Average formula

$$\% \text{ Error } = \left| \frac{\text{measured - accepted}}{\text{accepted}} \right| \text{x100}$$

Figure 4.28: Percentage error formula

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 INTRODUCTION

In this chapter will discuss the conclusion for this project that had done in this two semester and recommendation for the future research and experiment.

5.2 CONCLUSION

In this thesis, the motion capture system is applied to help the subject to improve the functional of their arm. In order to evaluate the performance, the physical activity as mentioned in Chapter 3 are conducted. Based on the result obtained, can be concluded that this project is successful. The objective of this project which are to analyze the movements behavior, monitoring the movements in real-time and used the offline data were achieved.

However this project have a few weakness. First of all, at the beginning of this project the analysis of the movements behavior are aimed at arm and leg. Due to the time constrain only the movement of arm can be conducted. Then, the calculation of the angle is not really same as the data sources and needs to manually calculate by using the Microsoft Excel. Lastly, this project collaborate with the professionals like doctors or physiotherapist for the analysis part.

5.3 RECOMMENDATION

In this project, there are some recommendations or improvements can be made to counter the weakness of this project. Firstly, further research should be done to complete the analysis for the movements of the leg. Besides that, the finding of the angle can be extend by using Inverse Kinematics method that more suitable and use technical software such as MATLAB. According to the accuracy, maybe it can be increase by calculate all the angle along the ShapeTape^{TM} sensor. Then, for further research able to analyze the movement in more details and make it display the graph directly without needs to make it manually.

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APPENDICES

Appendix A

Specification of ShapeTape^{TM} Sensor

sPECS

Detailed product specifications.

Spec	 Measurand S1280CS ShapeTape
Dimensions of tape	1.3 x 13 x 1800 mm nominal
Dimensions of interface box	6 x 54 x 168 mm nominal
Operating temperature	-20 to 50 deg c
Sensitive zone	outboard 480 mm contains 16 sensors arranged in 8 pairs
Sensor length	each sensor integrates curvature over a 60 mm portion of the sensitive zone
Sensor pair	each pair resolves bend and twist, using calibration constants
Calibration	Circle, twist, & flat poses yield stored calibration constants
Data	x,y,z and orientation at 16 or more points along sensitive zone, relative to inboard reference end
Calibrated Range of each sensor	± 40 mm radius bend; ±22.8 deg twist
Safe Bending radius	± 20 mm radius
Spatial sampling limits	each monotonic (single polarity) curve requires two sensor lengths
Operating range for end of 'U' shape	two elliptical volumes, 160 x 250 mm each
Endpoint accuracy within operating range and sampling limits	-3% of length is a reasonable expectation for postional errors; thus, for the first 100 mm of a tape, the error can be expected to be 1-3 mm, and if the tape is 1000 mm long, the error at the tip can be expected to be 10-30 mm.
Endpoint resolution	0.3 mm rms, x,y,or z; 0.5 deg, roll, pitch, or yaw
Other locations on tape	errors reduce toward inboard reference end, within range and sampling limits
Maximum data acquisition speed	110 Hz
Included	Wall mount power supply (60 Hz, 120VAC), serial cable, interface box, and tape