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Left Hand and Right Hand Throwing Mechanism Patterns Classification

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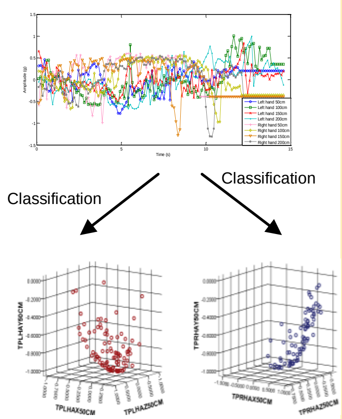
Graphical abstract



Abstract

This study investigates and acts as a trial clinical outcome for human hand motion and behaviour analysis. It was analysed and accessed the quality of human motion that can be used to differentiate the left and right hand throwing action patterns and also the effect of throwing distance to shoulder pain. It aims to establish how widespread the quality of life effects of human motion especially hands movement. Gyroscope, accelerometer and compass sensors were used to measure the hand movement for a throwing process. 2D and 3D scatter plotting were proposed to represent data in graphical form. An experiment was set up in a laboratory environment with conjunction of analysing human motion. The instruments demonstrate 2D and 3D scatter plot enable distinguish left and right hand throwing action patterns significantly. Distribution of gyroscope data shows that a throwing mechanism for a greater distance may bring greater probability of shoulder injury.

Keywords: Accelerometer; gyroscope; compass; motion; shoulder

Abstrak

Kajian ini menyiasat dan bertindak sebagai hasil percubaan klinikal gerakan tangan manusia dan analisis tingkah laku. Kajian dibangunkan untuk menganalisis dan mengakses kualiti gerakan manusia yang boleh digunakan untuk membezakan corak lontaran tangan kiri dengan tangan kanan serta penyelidikan usul manusia. Eksperimen bertujuan mengesan kualiti kehidupan gerakan manusia terutama pergerakan tangan. Sensor giroskop, pecutan dan kompas digunakan untuk mengukur pergerakan tangan untuk proses pergerakan melontar. Plot berselerak 2D dan 3D yang berkomplot telah dicadangkan untuk mewakili data dalam bentuk visual grafik. Eksperimen ditubuhkan dalam persekitaran makmal dengan menganalisis gerakan manusia. Instrumen menunjukkan plot berselerak 2D dan 3D mampu membezakan corak tindakan lontaran tangan kiri dan kanan dengan ketara. Pengedaran data giroskop menunjukkan bahawa mekanisme melontar untuk jarak yang lebih jauh boleh membawa kemungkinan yang lebih besar kepada kecederaan bahu.

Kata kunci: Pecutan; giroskop; kompas; gerakan; bahu

1.0 INTRODUCTION

Motion can be detected by sound (acoustic sensors), opacity (optical and infrared sensors and video image processors), geomagnetism (magnetic sensors, magnetometers), reflection of transmitted energy (infrared laser radar, ultrasonic sensors, and microwave radar sensors), electromagnetic induction (inductive-loop detectors) and vibration (triboelectric, seismic, and inertia-switch sensors).[1]

This study focuses on investigating the human motion and movement behavior through analyzing differentiating their hand throwing process pattern, to come out with a better solution for movement recognition and nature behavior analysis. The methodology of research is to get the throwing pattern through a few sensors attach on skin for further processing and analysis. The literature reviews from previous research on the requirement of experiment design and the current trend of analysis method will guide us to develop a good research framework.

The objective of this study is to investigate the human motion especially for hands movement of a throwing motion by analyzing the effect of distance of throwing to the motion of shoulder. Scatter plot was used to differentiate and categorized the left and right hand patterns for throwing motion. This paper presents a statistically way of motion signal processing technique, and presents ideas for further development, to give researchers ideas of how they can use human movement in related field for product development.

The research framework complies with the below model. The five phases—Sensor attachment, Data transmission, Data acquisition unit, Back end data processing, and Evaluation represent a dynamic, flexible guideline for building effective human motion analysis and movement classification.

This paper is divided into six sections. The first section mainly introduces the whole study. It provides the general overview of the motion and analysis system and the objectives of this study, which describes the aims that needed to be achieved. The second section discusses the background studies, literature review and the study implementation was discussed in section 3. A specification list of the computer environment and thorough discussion on the developmental method or assessment and analysis on both motions will be explained in section 4 and 5. Finally, the last section contains the conclusions, future developments and possible enhancement and improvement on this study.

■2.0 LITERATURE REVIEW

Shoulder pain is a common complaint among badminton player, softball player and baseball player, especially pitchers for baseball game. This complaint happened regardless of age and level of play. Refer to common "dead arm" syndrome, pain was experienced among these groups of players during throwing or smashing motion which may leads to inability to throw with desired velocity and ball landing coordination.[2]

It is important to understand both the anatomy of the shoulder joint and ball throwing mechanism in order to understand pain in throwing shoulder. As in Figure 1, a throwing process can be divided into 4 phases: wind up, cocking, acceleration and deceleration.

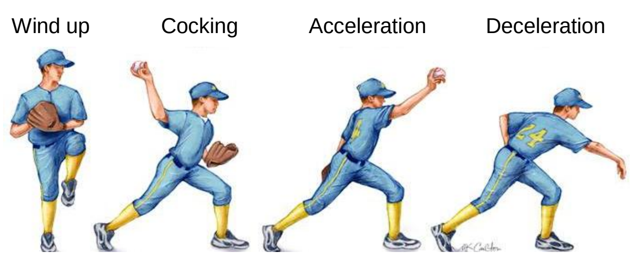


Figure 1 The four phases of throwing[2]

The shoulder is a ball-and-socket joint. It fits loosely in the socket and is unrestricted for all angle movement. The farther one is able to bring the arm back into abduction which it is able to raise away from the side of the body and external rotation in order to release a ball with higher speed. The soft-tissue stabilizers feel the greatest stress during the throwing motion and therefore, when this stress is applied repetitively, the most frequently the shoulder joint structures injured.[2-5]

Accelerometer, gyroscope and compass sensors are the most commonly devices used in movement detection and analysis system.[6] Introduction of human actions into digital domain is a primary driver for innovation of motion functionality. Human motion signal processing technique, which combines inertial measurement units with digital signal processing, enables people readily incorporate with performing correct motion mechanism.[7,8] Description below provides readers with understanding of the sensors combinations used in motion detection and analysis field.[9-11]

2.1 Accelerometer

The primary usage of accelerometer is measuring linear acceleration and tilt while velocity can be obtained by a single integration and relative distance by a double integration. The benefit of a accelerometer is that it able directly measure tilt angle and linear distance based on acceleration of gravity. The main drawback of the sensor is it unable to distinguish between acceleration due to linear movement and acceleration due to gravity. Problem can be solved by combining accelerometer with gyroscope sensor.

2.2 Gyroscope

Gyroscope mainly is used to measure absolute rate of rotation and relative angle by a single integration. The performance is fast and accurate without corrupted by linear acceleration or magnetic fields. However, sometimes the integration may lead to errors over time but it can be solved by combining with accelerometer.

2.3 Compass

Compass sensor measures magnetic fields. It has an absolute heading measurement. The sensor is very sensitive to outer magnetic sources or interferences. Hence, it required tilt compensation and the field corruption can be solved by using gyroscope sensor in conjunction with compass.

The first step of any statistical analysis is to first graphically plot the data. Graphical plots based on correlation are called scatter plots. Scatter plots can visually show the strength of the relationship between variables, the direction of the relationship between variables and whether outliers exist. The purpose of the scatter plots can indicate anything unique or interesting about the data.

A wide variety of human-machine interactions learning techniques have been used in human monitoring approaches for motion analysis. This employs a large number of visual and physiological features, a fact which usually impedes the training process.

■3.0 METHODOLOGIES

3.1 Study Sample

Five healthy volunteer were selected inside university campus for taking part in this study. Their age is around 20-25 years old with normal limbs movement and significant mobility in everyday routine independent of any walking aid with no athletic background. They are three males and two females with the average height approximately 160 cm and 50 kg in weight with dominant of right-handed for daily activities.

3.2 Experimental Setup

For this preliminary study, experimental setup was done using a wireless 3-axis accelerometer. This device employs a YEI 3-Space Sensor breakout board for the tri-axial gyroscope, accelerometer, and compass sensors. The sensor performs advanced processing and on-board quaternion-based Kalman filtering algorithms to determine orientation relative to an absolute reference in real-time in an enclosure measuring 60 mm × 35 mm × 15 mm. The device was connected to a laptop using a standard USB 2.0 host system wireless asynchronous serial transmission.

The subject wore wearable sensors on above left and right hand as in Figure 2 which employed of three sensors (gyroscope, accelerometer and compass) inside the package. These sensors were attached firmly on subject's skin with a special designed holder.

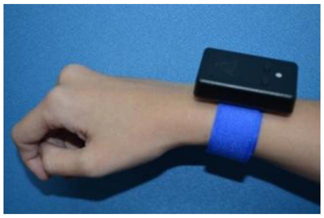


Figure 2 Attachment of sensor on left and right hand

As in Figure 3, the subject was sitting on a static chair and throwing a paper ball with a radius of 3 cm and 2 g in weight to the targeted different locations (50 cm, 100 cm, 150 cm, 200 cm away from the static chair), with left hand for 10 throwing then followed by right hand. The sitting pose was aimed to eliminate the movement of subjects in order to provide a static situation for sensor in detecting the arm movement.

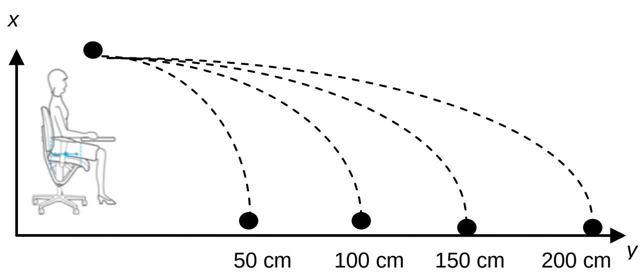


Figure 3 The Throwing task of four different length of target

Accelerations due to jolting of the sensors if loosely attached may add noise to the signal.[12] The specially designed sensor holder is attached firmly to the subject's skin to avoid any possible disturbance.

3.3 Data Collection and Management

In the initial phase of the trial study, experiment was conducted for two activities; left hand and right hand throwing actions. Subject was asked to perform a normal throwing action to the targeted destinations with left hand then follows by right hand. This activity was performed in a supervised and comfortable environment with presence of researcher for time-stamping the start and end time of throwing period.

Subject was encouraged to perform the throwing activity at his own pace and convenience. The whole experiment setup place was ensuring a relaxing and natural mood for the sake of subject for reflective of real world conditions.

3.4 Data Analysis

Once data collected is transmitted from sensor to laptop through wireless dongle, the data then is transferred into MATLAB for further processing.

Raw data were firstly presented in time domain graph, and then the data were processed for better visual graphical form representation. 2D and 3D Scatter diagrams were plotted and descriptive statistical data were presented in tabular form. Descriptive statistical data includes minimum values, maximum values, mean, median and standard deviation.

All the processing algorithms and methods were coding in MATLAB signal processing toolbox platform and results were shown in GUI.

3.5 Instrument Revision

The preliminary set of outcome measures was shown in Figure 3 and Figure 4. There are 3 sensors used in this experimental setup: gyroscope, accelerometer and compass. The ability of the sensors in differentiating and describing the throwing patterns was distinguished in discussion part.

In order to ensure the scope of the study, accelerometer values in x-axis are focused since it is where the effect was took place in the horizontal motion of hand movement towards the targeted destination.

■4.0 RESULT

The study is still in a preliminary stage and yet we had conducted this pilot test on data collecting and analyzing and therefore significant preliminary results had been generated. A time domain plot of the tri-axial accelerometer signals of one subject for throwing activity is shown in Figure 4. It can be seen the dynamic activity can be identified by the orientation of the accelerometers, simple threshold and scatter plot analysis.

In Figure 4, around 120 samples data were collected and plotted in a time domain graph with sampling frequency, Fs=8Hz. The subject was required to perform a throwing activities with right and left hand for vary targeted distance. The descriptive statistics for time domain signal of accelerometer in x and y axes are tabulated as in Table 1. The statistical data include min, max, mean and standard deviation. The overall mean values for x-axis are drop at the boundary -0.83g until -0.44g. The highest standard deviations for x-axis (horizontal acceleration of hand movement) are 200 cm target distance for left and right hand. Standard deviations values for Y-axis (horizontal acceleration of hand movement) are overall higher than x-axis.

There is not much of depth information revealed from time domain plot and hence, scatter plot was used to present the data in 2D and 3D as in Figure 5 and Figure 6. In order to obtain a clearer and cleaner approximation plot, data received from the sensors was pre-processing using averaging filter to eliminate DC noise. Then the data was post-processing for plotting scatter plot.

In Figure 5, data of gyroscope, accelerometer and compass are presented in 2D scatter plot. For left hand throwing activity, data from sensors (accelerometer and compass) are dropped at the upper left quarter given zero as the central reference while data for right hand throwing activity dropped at lower right quarter. Figure 6 clearly describe the 3D plot of accelerometer data for left and right hand. Left hand and right hand throwing patterns can be easily differentiated by visually analyzing the plot. Accelerometer data from a left hand throwing pattern are distributed and skewed to left while right hand throwing patterns are skewed to right.

Table 1 Descriptive statistic for time-domain signal of accelerometer in X and Y axes

Variables	Sample		Min		Max		Mean		Std. Deviation	
	X	Y	X	Y	X	Y	X	Y	X	Y
Left hand 50cm	124	101	-0.9996	-0.9789	-0.1218	0.2586	-0.814269	-0.201035	0.1978162	0.2780508
Left hand 100cm	124	117	-0.9931	-0.9574	0.1278	0.6500	-0.643617	-0.353044	0.2585467	0.4043929
Left hand 150cm	124	124	-0.9988	-0.7942	0.1954	0.5652	-0.831155	-0.279025	0.1716570	0.2375810
Left hand 200cm	124	124	-0.9960	-0.9250	0.6250	0.7432	-0.697810	-0.250779	0.2604978	0.3807283
Right hand 50cm	124	81	-0.9996	-0.6007	-0.0632	0.9906	-0.629244	0.385185	0.2656520	0.4192114
Right hand 100cm	124	102	-0.9986	-0.6187	0.2342	0.9226	-0.708871	0.351652	0.2892238	0.3763687
Right hand 150cm	124	86	-0.9926	-0.8894	0.6438	0.8949	-0.493552	0.390667	0.3018025	0.3901179
Right hand 200cm	124	103	-0.9895	-0.8713	0.6988	0.9793	-0.448626	0.436086	0.4617221	0.4158139

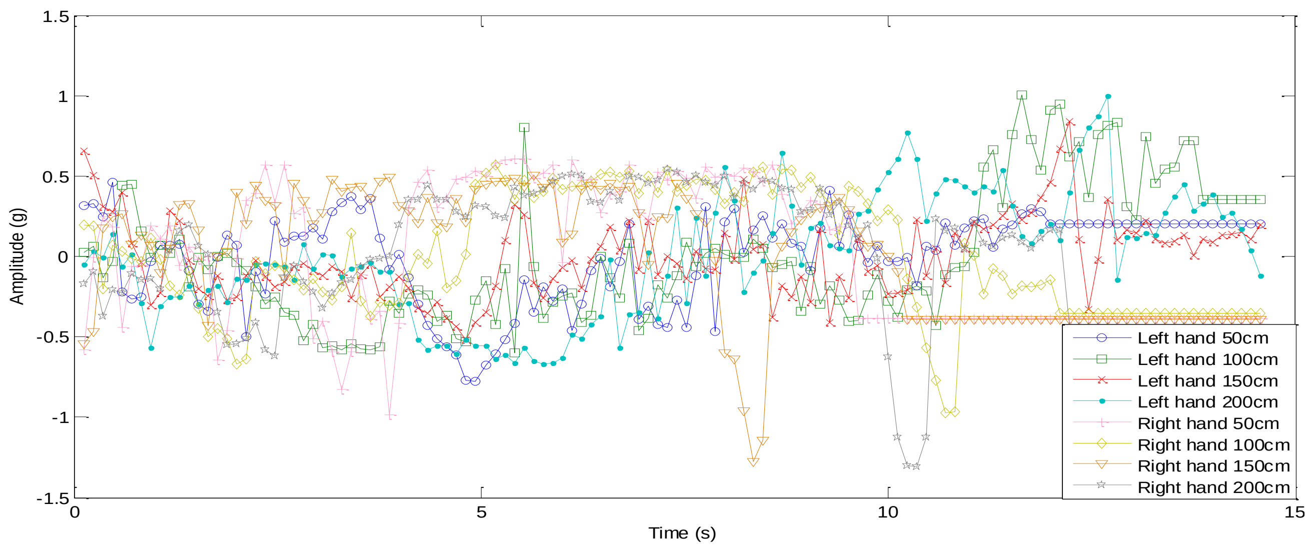


Figure 4 Time domain plot for descriptive statistical data

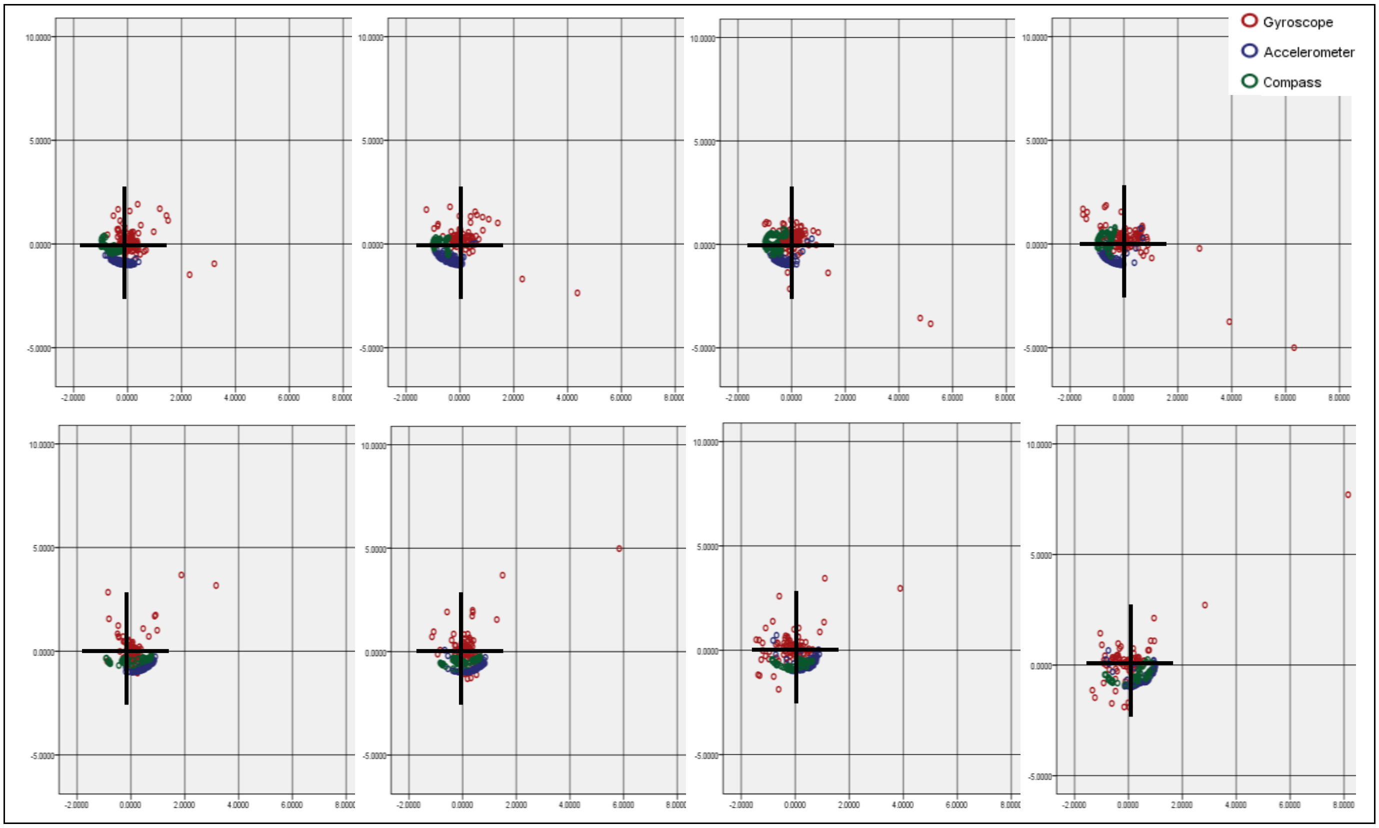


Figure 5 2D scatter plot for gyroscope (red), accelerometer (blue) and compass (green) of left hand (above) and right hand (below) for 50 cm, 100 cm, 150 cm and 200 cm

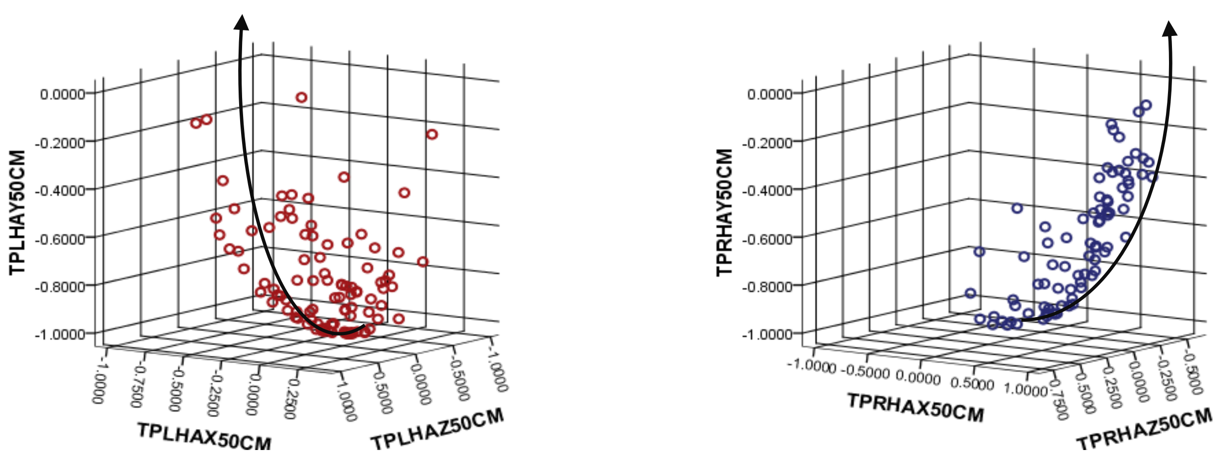


Figure 6 3D scatter plot for accelerometer of left hand (left) and right hand (right)

■5.0 DISCUSSION

Generally, it was considered appropriate for the initial phase of the quantitative study to be conducted in a laboratory environment. Further work is planned to increase the sample size and to encompass different environments in both the dynamic and transition activities.

Normally, presenting signal in time domain seldom reveals depth information. In order to differentiate the activity of throwing by left and right hand, data from gyroscope, accelerometer and compass are presented in a scatter plot.

Referring to Table 1, the maximum values of the sensed amplitude for right hand movement are more than 0.85 g while left hand values are recorded in between 0.25 and 0.75 g. The standard deviation and mean values for right hand categories are higher than the left hand. It is due to the dominant use of right hand of the subjects. Their preferably right hand is always use for every single motion and movement and hence the smoothness, fluency and continuity of motion performed by right hand is always higher than left hand. This leads to a larger movement by right hand rather than a left hand whenever a task was requested. Left hand of a right-handed person was controlled by many factors like unsteady motion for unusual movement, tremor due to irregular movement, shaking, swaying and concussion.

2D scatter plot was proposed to distinguish the throwing patterns of left hand and right hand. Patterns are easily differentiated by analyzing the location of the distribution of data. Data (accelerometer and compass in Figure 5) distributed at upper left quarter is represented left hand throwing motion while lower right is right hand throwing motion.

Besides, referring to Figure 5, as we focus on accelerometer data which represented by red dots markers, as the targeted distances increased, the amplitudes of x-axis of the outermost x-axis value were also increased.

Surprisingly, 3D scatter plot gave a clearer and accurate result for the throwing motion. As in Figure 6, the direction of skewedness of the data distribution can be used to represent the hand motion patterns.

One but not the only one straight forward application for this research is motion recognition. It also can be applied on the incredible thing likes gesture recognition, behavioural analysis and gait analysis.

There is also a possibility of incorporating an EEG and ECG into this study. ECG could be used to study the condition of human body while wearing sensors and EEG could be used to study the condition of human brain activity while performing task. This data should be working in parallel with accelerometer.

■6.0 CONCLUSION

In order to fully realize this study, there are few things that could be considered, the main feature of interest is the data processing unit. All data are processed under the same platform without bias. Further approach need to be taken in order to achieve a higher aim in this research.

The gyroscope accelerometer and compass sensors are proved to be a highly effective motion sensor for physical activity assessment. The proposed method of analyzing data is able to differentiate the left and right hand throwing action patterns. Results show that a greater motion is needed when performing a throwing action for a greater distance, and may create a greater probability for shoulder injury.

The sensor is capable to filter and normalized data using Kalman filter. Results presenting in scatter plot successful reveal information needed. The attachment of sensors on subject's skin was firm without significant disturbance such as jolting noise. Overall this study completed the objectives from attachment, detection, orientation, transmission, receiving, filtering, and analyzing.

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