Evaluation of Kinect Sensor in Mechanical Horse Simulator for Equine-Assisted Therapy

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***Abstract*—Equine-assisted therapy (EAT) is one of therapy strategy practiced for disabled people to improve physical functions which can be performed using either real horse or mechanical house simulator. In EAT based on horse simulator, there is no automatic tracking tools that are being used to track movement, speed, position or posture of rider on horses during equine-assisted therapy. Hence, this study aims to evaluate the potential application of Kinect as the sensor for automated tracking of rider speed on a mechanical horse simulator. This sensor is used to capture skeletal data of rider riding mechanical horse simulator for three increasing speed and to analyze the skeletal data using the boxplot approach. From 25 human joints that could be detected, there are four joints that are significance and stable joints to represent the speed which are joint 2 (neck), joint 3 (head), joint 4 (left shoulder) and joint 8 (right shoulder).**

***Index Terms*—Equine-assisted Therapy (EAT); Kinect V2; Mechanical Horse Simulator.**

I. Introduction

Parents of physically-disabled children such as cerebral palsy, multiple sclerosis and spinal bifida send their children to participate in equine-assisted therapy (EAT) to improve their physical conditions including balance and coordination, body posture and muscle tone [1]. In general, the therapy can be performed either using the real horse or mechanical horse simulator. Although the therapy had been practiced for many years, the therapists only assess the participant improvements using manual methods after the therapy session. Sometimes, the assessments are solely based on subjective observations by the parents and therapists.

In EAT based on mechanical horse simulator, there is no automatic tracking tools that are being used to track movement, speed, position or posture of rider on horses during equine-assisted therapy. This study aims to evaluate the potential application of Kinect as the sensor for automated tracking of rider speed on a mechanical horse simulator. The 3D skeleton joints coordinate by Kinect's depth sensor are used for formulating physical parameters specifically the average frequency in predicting the rider speed for future application such as gait or kinematic analysis.

II. Related Works

A. Equine-assisted therapy

Horse is one of animal that are widely used in therapies because of its positive after-effects. Horse have special characteristics such as they are easily trained, adaptable, and sensitive to non-verbal stimulus thus making it easier to build bond and offer unconditional friendship with human [2]. The large and powerful physical build of a horse also plays significant role where it causes them to be threatening to some people. This will challenge people that follow the therapy to overcome the fear thus motivating them to be more confident with higher self-esteem [2].

The physical benefits of equine-assisted therapy to human could not be denied as activities with horse such as riding is also considered as one type of exercise for human. The rhythmic and repetitive movement of horse happen to be similar to human gait so it could assist to improve rider's posture, muscle strength, balance and coordination [3]. Many research had been done to prove the effectiveness of the therapy to disabled people.

A study in Turkey investigate physical performance of children with cerebral palsy which compares a group of nine children that received horseback riding in addition to conventional rehabilitation and a group of seven children that only received conventional rehabilitation [4]. The study assessed the modified functional reach test (MFRT), hip abduction angle, the Ashworth Scale for hip adductor muscle spasticity, knee distance test, and the Gross Motor Function Classification System (GMFCS) before and after five weeks of rehabilitation. From the results, the group that experienced horseback riding gave better outcome where their adductor spasticity changed 20 percent while the other group adductor spasticity did not change at all [4].

Study in [5] investigated the effects of equine-assisted therapy on gross motor function and quality of life of children with psychomotor impairments including Down syndrome, cerebral palsy, Dandy-walker syndrome and IDIC-15 syndrome. Two types of equine-assisted therapies were done; hippotherapy and therapeutic horseback riding. The Gross Motor Function Measure (GMFM-88) was measured to assess various areas which are lying, sitting, crawling, kneeling standing, and walking. The quality of life was evaluated based on Pediatric Quality of Life Inventory (PedsQL). The assessments were done three times; and the results conclude that equine-assisted therapy improve gross motor functions based on the changes of GMFM-88 scores of the children while the improvement on quality of life is modest and not too significant [5].

In the other hand, two studies [6-7] had investigated the effect of equine-assisted therapy to children with bilateral spastic cerebral palsy (CP). Bilateral spastic CP is a subtype of CP where it involves both sides of limbs and individual with bilateral spastic CP usually have problem to control their posture while standing [6]. The first study [6] did the spasticity evaluation based on Modified Ashworth Scale (MAS) and gait evaluation using sensor to detect acceleration signals to obtain spatial-temporal gait parameters while the other study [7] analysed the gait parameters for example pelvic and hip kinematic parameters in 3-dimensional motion analysis, Gross Motor Function Measure and Paediatric Balance Scale (PBS). Both studies proved that the equine-assisted therapy improve gait and balance of the children.

Regardless the positive outcomes observed from EAT, some issues arise such as the high economic cost, lack infrastructure, and possibility of accidents occur causes it rather hard to be implemented commonly in our society [3]. To overcome these problems, horse simulator had been introduced where it mimic closely real horse movements and show similar effective outcome to therapy using real horse [3]. There are many brands of horse simulator available in market with distinctive features for different needs, price range and design.

B. Kinect for Rehabilitation

Kinect (see Figure 1) is a series of motion sensing device produced by Microsoft which are originally introduced for Xbox360 and Xbox One video games console and Windows PC [8]. Nowadays, it has been used extensively for many research and studies such as object tracking, motion analysis, hand gestures recognition and augmented reality [9].

Kinect consists of colour sensor that capture RGB image and depth sensor that capture the image in 3D [9]. The low-cost Kinect is able to tracks people and their full body postures within its field of view at the real-time rate of 30 frames per second [8]. The latest version of Kinect for Windows is Kinect V2 which is the upgraded version of Kinect V1.

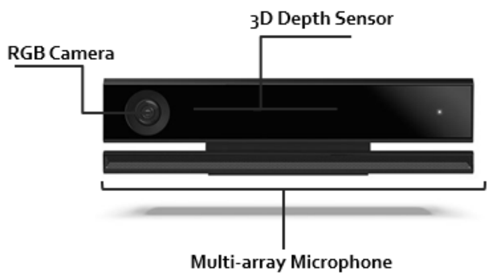


Figure 1: Kinect for Windows V2

Kinect V2 provides expanded field of view, captures image with higher resolution, higher pixels, and capable of tracking 25 skeletal joints (see Figure 2) of maximum 6 people, compared to 20 skeletal joints of maximum 2 people only in the previous version [8]. The detection of the skeletal joints is called skeletal tracking.

One example of Kinect usage is as development of interactive rehabilitation systems. As an example, rehabilitation system for the lower limbs using Kinect [12] is one of an innovative project done. Kinect was used to acquire real-time body movement image from skeleton tracking function. Other than that, a supervised training rehabilitation system at home for injured athlete also use Kinect for full-body 3D motion capture and gesture recognition, where it keeps the athlete motivated to follow the therapy throughout the recovery period with it gaming concept [13].

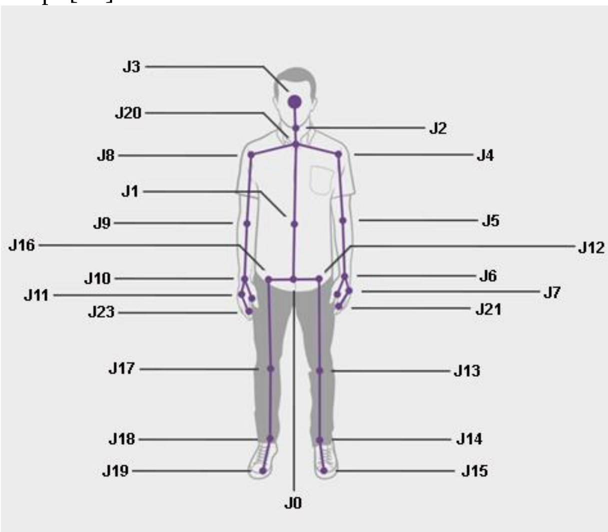


Figure 2: 25 skeletal joints relative to the human body that can be detected by Kinect for Windows V2 (adapted from [10])

Besides that, Kinect was use as data analysis of rehabilitation in many research. In a study to measure kinematics parameters of gait, the Kinect for Windows V2 was compared with GAITRite mat, an electronic walkway [8]. Although the Kinect has both advantages and drawback in comparison with GAITRite, the study proved that Kinect for Windows V2 is reliable for gait analysis as it has the ability to capture kinematics and joint motion [8]. Another project had investigated the reliability of Kinect to measure shoulder joint angles for virtual rehabilitation. The findings of this research verify that Kinect is highly reliable for the measurement of shoulder angle poses especially during abduction to 90° pose [14].

Kinect has high potential to be beneficial in innovative rehabilitation system that act as an added value as it is a low-cost device, portable, and has great performance in motion analysis compared to other existing 3D motion capture system.

III. METHODOLOGY

A. User Need Assessment

The first step is user need assessment. User need assessment is a process to get information from user to solve their problems. User need assessment is crucial to meet the demands of user which in this study are the therapists and RDA coaches. From the assessment, the problem faced by user and their preference to solve the problems were identified from user point of view. The assessment was done by interviewing user during RDA class session.

B. Materials

This project used a mechanical horse simulator with brand Equicizer Classic as the medium for equine-assisted therapy and the Kinect V2 sensor captured data of the rider during the therapy. Matlab Image Acquisition Toolbox Support

Package was used to acquire image sensor data directly from Kinect into the computer.

C. Data Collection

As mentioned before, Kinect V2 could detect up to 6 bodies (25 joints on each body) for each scene. However, in this works, the algorithm was designed to detect only one body per scene. Thus, the Kinect was programmed to detect only one body, which is the body of the rider on the horse simulator. Figure 3 illustrates the experimental setup for this study. The Kinect camera was placed 4.5 feet behind the horse simulator to capture image of the rider sit from back view to obtain the full view of the skeleton joints. 15 subjects, 10 males and 5 females of Equine Management student were asked to perform the riding activity on the horse simulator. Every subject was asked to perform three sessions of horse riding activities which are for slow, medium and fast speed depends on the subject capability before the 3D skeleton joints coordinate was recorded as shown in Figure 4. From the collected data, only z-value of joint coordinates were highlighted since riding activity mostly involved forward and backward movements and z-value are the most appropriate information that can represent such movement.

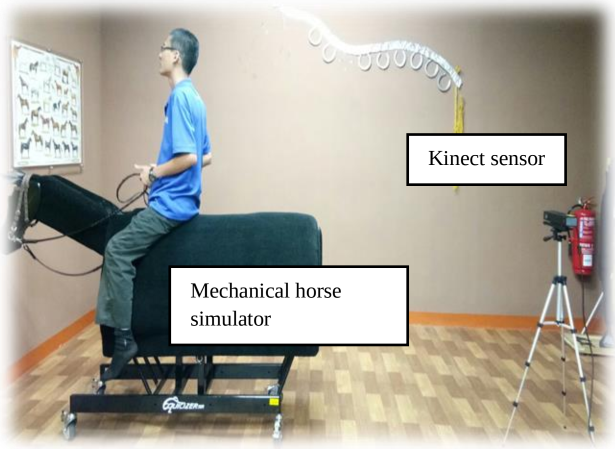


Figure 3: Setup for data collection

Figure 4: RGB with skeletal tracking image of rider on Equicizer

D. Data Analysis

The mean frequency was formulated from the z-value that represents the forward and backward movement of each rider in three different sessions (low, medium and fast speed). Thus, for every subject per session, there were 25 mean frequency value; each represents each joint detected by the Kinect. Boxplot graphs of the mean frequency value were established to identify the salient joint coordinate that can be used to represent the rider speed.

As mentioned before, the boxplot was used to evaluate which joints that were most suitable to be selected to represents rider speed on the mechanical horse simulator. This was done by calculating average percentage of overlap mean frequency range of each joint (percentage of overlap between one boxplot to another). Firstly, the percentage of frequency overlap between slow and medium session and followed by medium and fast session percentage of frequency overlap were calculated. Then, the average between the two percentage were computed using the following equation.

$$Average\ \%\ of\ frequency\ overlap = \frac{(overlap\ 1 + overlap\ 2)}{2} \tag{1}$$

Whereby

$$overlap\ 1 = \frac{range\ of\ slow\ and\ medium\ overlap}{range\ of\ medium} \times 100 \tag{2}$$

$$overlap\ 2 = \frac{range\ of\ medium\ and\ fast\ overlap}{range\ of\ medium} \times 100 \tag{3}$$

The calculated percentage values for all joints were represented in bar chart graph to rank the lowest percentage of overlap to the highest percentage of overlap.

IV. RESULT AND DISCUSSIONS

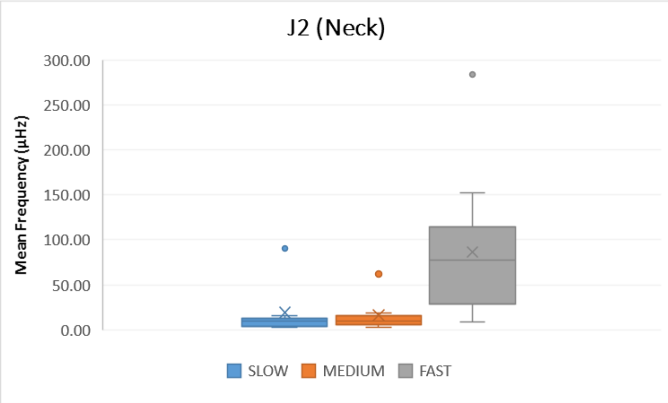
A. User need assessment

The interview findings are:

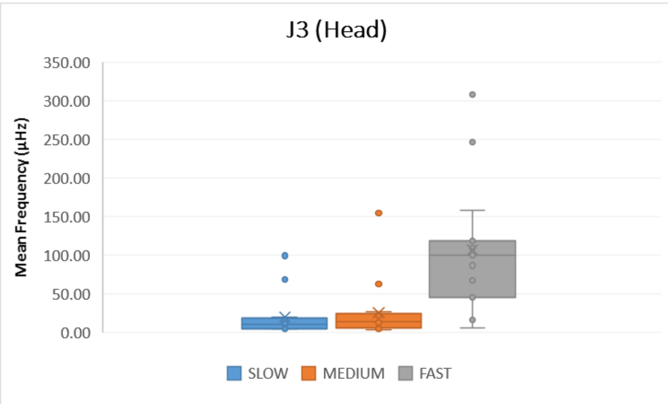
i. Children such as cerebral palsy and spinal bifida follow equine-assisted therapy to improve their physical functionality.
ii. One of the way to evaluate the rider physical condition is based on her/his posture on horse (central, upright position- vertical line from head, shoulder to hips and then leg).
iii. Up until now, there is no automatic system to track physical condition of rider (physically-disabled children) so they hoped for an automatic system with interactive graphical user interface for equine-assisted therapy.

B. Data Analysis Result

From the recorded z-axis joint coordinates (1D signal), the frequency components of joints were formulated using the fast Fourier transform (FFT) before the mean frequency was computed. This process was done in each joint that represent the three different sessions (slow, medium and fast). After that, these mean frequency values were used to generate the boxplot for each 25 skeleton joints. Figure 5(a)-(e) show the example of boxplot graph that represent five different joints; J2, J3, J4, J8 and J9 (actually there are 25 boxplot graph that represent 25 skeleton joints. Only five best candidates or best joints were displayed since it is impossible to display the entire 25 boxplot graphs).



(a)



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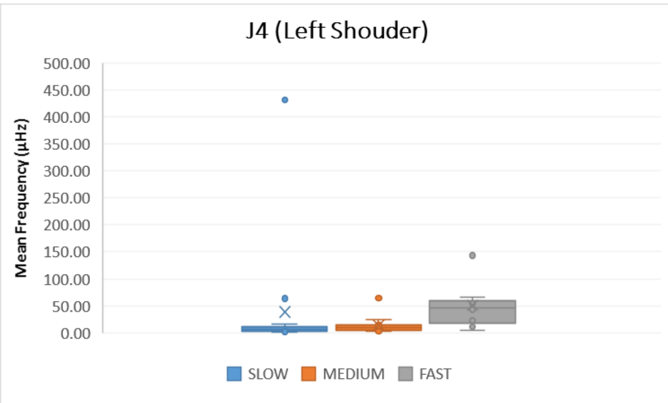

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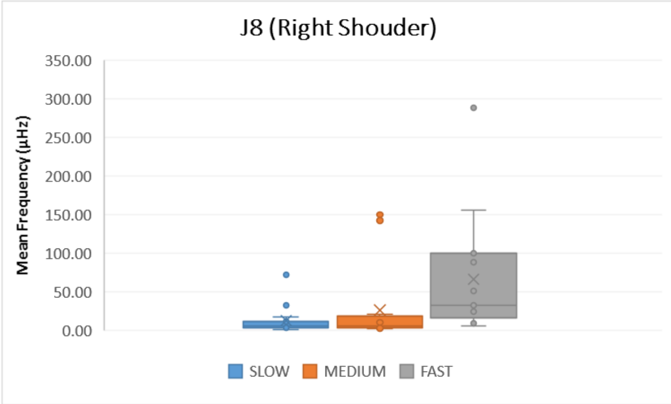

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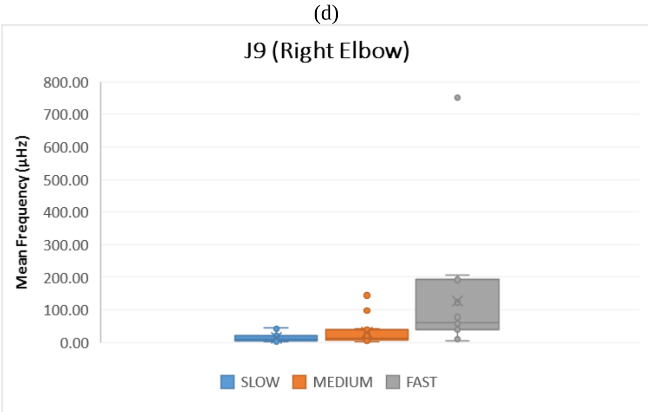

(e)

Figure 5: Boxplot graphs showing mean frequency range of joints: (a) Joint 2-neck (b) Joint 3-head (c)Joint 4-left shoulder (d) Joint 8-right shoulder (e) Joint 9-right elbow

From the graphs, although most mean frequency range were overlapping between each other especially between slow and medium speed sessions, all joints showing increasing frequency range indicating different speed of riding made by the subjects. This indicates that using the skeletal tracking function in Kinect sensor is reliable to detect motion of rider on a mechanical horse simulator. The overlapping data between slow and medium sessions were likely because of the subjects may unable to make much different effort on the two different speed sessions.

Based on boxplot graph, the average percentage of frequency overlap range for all 25 joints were calculated using Equation (1) and represented in bar graph illustrated in Figure 6.

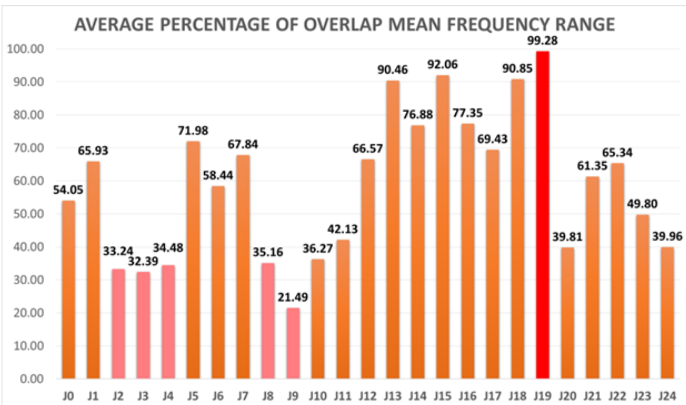

Figure 6: Bar graph of average percentage of overlap mean frequency range

As mentioned before, Kinect V2 could detect 25 skeletal joints. To evaluate which joints that are most suitable to represent rider speed riding on horse simulator, the joint with frequency range of one session has least overlap with other session should be picked. This is because the capability of selected joints in differentiates the different range of speed will prove that the joints are highly sensitive to the change in speed. As we can see from the bar graph in Figure 6, the lowest percentage were J9 (right elbow), followed by J3 (head), J2 (neck), J4 (left shoulder) and J8 (right shoulder). However, J9 which is right elbow was not considered to be chosen as reliable joint because it's pair, joint 5 (left elbow) has percentage of overlap of 71.98% which is considered very high. Besides that, movement of elbow are not significant in representing the movement of riding horse. Thus, the best selections are head, neck, left and right shoulder.

In addition, the selected joints which are head, neck and both shoulders are also matched with a half of the 'central, upright position' used by RDA therapist to evaluate posture condition of rider which is vertical line from head, shoulder to hips and then leg.

V. CONCLUSION

As a conclusion, skeletal data of z-axis of all 15 subjects riding on horse simulator for three different speed were collected using Kinect for Microsoft V2 sensor. The mean frequency of each joints was formulated using simple function in MATLAB. The frequency component was used for data analysis to evaluate the ability of Kinect skeleton joints to detect speed and to choose best skeletal joints that represents the rider speed.

Using skeletal tracking function, Kinect is suitable tool to detect movement of rider in terms of speed on mechanical horse simulator. This is proven by increasing trend in boxplot graph of mean frequency for all joint. From 25 joints that could be detected, there are four joints that are significance and stable joints to represent the speed which are J2 (neck), J3 (head), J4 (left shoulder) and J8 (right shoulder).

Speed of rider on horse simulator could be one of parameter for gait analysis for the physically-disabled children. As Kinect simply detect 3D image using depth and colour sensor, it had advantage where it automatically assesses rider on horse simulator without any attachment of wire or anything else on rider body that could disrupt therapy session.

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