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Equine Gait Recognition using Wearable Technology for Endurance Monitoring: A Preliminary Study

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Abstract:
To overcome limitation in equine gait monitoring, a low-cost monitoring device is needed especially for long-distance event performance monitoring. Current devices capture horse gait in limited range of distance, limited duration usage and expensive. Mobile application such as Androsensor has shown a great potential in horse gait recognition. However, further study is still warranted in order to determine the reliability of this kind of mobile application for performance monitoring especially for long-distance event such as endurance. In this study, a validation test of Androsensor mobile application for equine gait patterns recognition was conducted before the data can be applied for long-distance performance monitoring. Two horses (Thoroughbred) were used in this preliminary study. A unit of inertia measurement unit sensor (IMU) (Delsys Trigno Avanti Sensor) with 150 Hz sampling rate and a mini smartphone installed with Androsensor apps with 200 Hz sampling rate were attached together on horse forelimb pastern to compare the acceleration of horse gait signal captured by both devices. The data captured by both devices were analyzed. The correlation coefficient between an established device (IMU) and the Androsensor apps have shown a good correlation with higher correlation coefficient ($r > 0.5$) for walk, trot and canter. This finding indicates that the Androsensor mobile application has a great potential to be used in equine gait research and performance monitoring. It also can offer a wide function in this field as it is cheap and wearable.

Keywords: Equine gait pattern; Signal processing; Inertial measurement unit.

1. Introduction

Nowadays, the application of wearable technology is widely increases in research for a better living experience such as in human wellbeing, safety, and leisure. For sport, wearable system or devices has been used to measure and monitor performance. Like in equestrian sport, wearable device such as accelerometer or inertia measurement unit (IMU) has been used to monitor equine performance [1]. For example, previous research was conducted to identify the accuracy of equine gait signal and created gait pattern for horse walk, trot and canter using IMU sensor [2].

Equine gait research field had evolved from 2009 until 2020 and showed increased in interest of using 2D to 3D image/data analysis. In the beginning, researcher or rider commonly used a simple camera recording to capture horse movement frame by frame to monitor equine performance [3,4]. Recently, wearable device technology has evolved with application of accelerometer, infrared technology and IMU [5,6]. The evolvement of these wearable technology makes horse gait easy to read instead of manually identify horse gait pattern based on observation of the limb movement.

2. Equine Gait Pattern Monitoring Technology

Equine gaits consist of three main gaits such as walk, trot, and canter which are essential in daily activity and equestrian performance [7]. Equine walk can be defined when four footfalls evenly space in lateral or diagonal and always has two feet on the ground. For trot, the gaits are symmetrical running gait with having two footfalls (diagonal pairs) per stride. Canter has three footfalls per stride leading limbs on the same side at the fore and hind move [8,9]. In easy comparison, the walk has four footfalls, trot has two footfalls, and canter has three footfalls in every stride.

Endurance event performances very much related to equine gaits of trot and canter [10]. During this event, trot applied the most during veterinary checks point which normally take 30-50m straight lines [6]. In previous research conducted for 120 KM of endurance event, there was no specific equine pace or gait pattern was used by the endurance horses [11]. Thus, it is difficult for the horse owner especially the rider to strategize or train the horse for the competition. Recently, application of the accelerometer and automated electronic timing are the latest technology that has been used in equine research [11,12]. Accelerometer and IMU seems to be the most relevant device to be used for long distance performance monitoring as it is wearable, and able to capture the horse gait in detailed.

Table 1 shows the comparison of wearable technology used for equine gait recognition. Four main research focused on the use of wearable sensor for equine gait study and evaluation of different placing setting of device has been compared. Based on the table, frequency domain features were used in most of the studies because it is easier to be analyzed. Androsensor mobile application has shown a potential in long distance performance analysis. It has been used before to identify horse-rider coordination using trot and canter movement [12].

Table 1**.** Comparison of wearable sensor technology used for equine gait recognition

Authors	**[9]**	**[12]**	**[2]**	**[7]**
Device	IMU	Androsensor	Androsensor	Locometrix, Equimetrix
Sensor	Acceleration	Acceleration	Acceleration, Gyroscope	Acceleration
Axis	x, y, z	x, y, z	y, z	Y
Sampling Frequency (Hz)	200 -500	8	50	100
Features	Frequency domain	Frequency domain	Time domain, frequency domain, wavelet	Frequency domain
Body Location	Head, withers, pelvis	Head, forelimb, hindlimb	Saddle - girth	Saddle - girth
Gait	Walk, trot, canter	Trot, canter	Walk, trot, canter	Trot

There is also an established mobile application such as Equilab and Gallopica that detect the horse gait pattern based on the movement of the mobile phone which is placed on the rider's body and Global Positioning System (GPS) respectively. These applications track the information such as speed, distance and time. But they do not provide information about the actual type of gaits performed based on actual equine kinematics.

Due to that limitation, this study aims to determine the correlation between Androsensor mobile application with an established IMU sensor (Delsys Trigno Avanti) to capture horse limb movement during gait movement. The findings can be used to develop a reliable endurance performance monitoring.

3. Methodology

3.1 Horse preparation

Two healthy horses (Thoroughbreds) weight of 415 ± 21.21 kg and height of 144.5 ± 21.92 cm from Equine Park, Universiti Teknologi Malaysia (UTM) were recruited as a subject for this study. Subjects were ridden by an experienced rider.

3.2 Data collection

One IMU Delsys Trigno Avanti sensor and a mini smartphone were attached together at horse pastern at forelimb as shown in Figure 1. Rider was asked to ride for walk (4 mph), trot (8-12 mph), and canter (12-15 mph) for two rounds of each gait types at the open arena of 20 m x 60 m. Rider and horses were given 5 minutes rest in between each trial.

Acceleration signal was captured using the onboard sensor of a Soyes XS 11 mini smartphone running Android 6.0. The phone measured 88.3 x 42.7 x 9.8 mm and weight of 130 gram. The phone was inserted into an armband with polyester composition and weighted around 30 grams. The phone was then installed with Androsensor application to record accelerometry data. The onboard accelerometer was set to record acceleration on the x-, y-, and z-axis at a sampling rate of 200 Hz frequency. One IMU Delsys Trigno Avanti Sensor with weight of 14 g attached together with the mini smartphone in the same armband attached at horse forelimb pastern.

Data collected from Delsys Trigno sensor were transferred via build-in Wifi to Delsys Base Station which allow wide area connection coverage meanwhile data collected from Androsensor were recorded and save in the mini smartphone. Both data then transferred into processing computer in Excel format via Bluetooth for signal conditioning and processing. Video recording for each trial also recorded for reference purposes.

Figure 1. Equipment setup

3.3 Data analysis

Acceleration data captured from both IMU sensor and Androsensor apps were analyzed using MATLAB software. The data captured were represented and manually identified the horse's acceleration and deceleration for stance and swing phase of each stride based on recorded video. In this study, Fast Fourier Transform (FFT) features was used to analyze the dominant frequency for IMU Delsys sensor and Androsensor apps. The dominant frequency from FFT show the highest peak of the frequency spectrum [1].

Both data were converted into hertz (Hz) unit. Each data was windowed to 5 seconds for each walk, trot, and canter trials. A Butterworth high pass filter (2 Hz) was used to remove the drift created during data collection. Detrend function also applied to maintain the signal at the 0 axis. After filtering and detrending the selected signal, the data were processed using FFT to determine the peak frequency value of all trials.

For correlation study, correlation coefficient formula is used to measure the correlation of these devices. Correlation of signals captured by both sensors were analyzed using the formula shown in (1), where x_i is values of the x-variable in a sample, $\bar{x}$ is the mean of the values of the x-variable, y_i is values of the y-variable in a sample and $\bar{y}$ is the mean of the values of the y-variable. With correlation coefficient, validation data for gold standard Delsys with Androsensor can be applied.

$$r = \frac{\sum(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\sum(x_i-\bar{x})^2\sum(y_i-\bar{y})^2}} \quad (1)$$

4. Result and Discussion

4.1 Observation of equine gait pattern

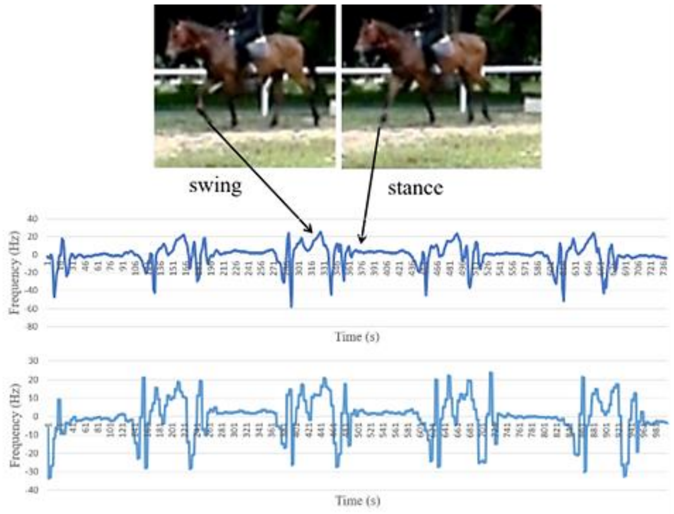
During the recording session, at least 5 cycles of gait can be captured for each round of trial. The pattern of a signal can be differentiated by referring to recorded video and time of completion. Walking speed is slower at around 4 mph, follow by trot with medium speed around 8 to 12 mph, and canter which is much faster at around 12 to 15 mph. Acceleration and deceleration for each gait also seem different. The fastest the gait, the higher the amplitude of the signal would be. Figures 2 below shows the different signal pattern captured from the Delsys Trigno sensor and Androsensor apps for a walk, trot, and canter. Acceleration of horse hoof pattern was observed at the swing phase meanwhile and deceleration of horse hoof pattern was occurred during stance phase of horse walk, trot, and canter. Different resting time interval was observed between gait type. Walking pattern has bigger rest time interval which indicate longer time for four footfall phases. But it is not observed during trot and canter. Canter have higher acceleration amplitude compared to trot and walk type.

In this study, Androsensor apps setting was changed for the graph height, graph value, interval and recording interval. The recording interval was set for 0.005 s to captured 200 values in a second and thus, increase the data resolution. By comparing captured data resolution, even though Androsensor apps sampling rate was set to 200 Hz, it is observed that the data captured by Delsys Trigno sensor was more precise and smoother. However, this limitation seems might not affect the accuracy of the data captured for equine gait recognition purpose as each gait pattern was observed differ from each other.

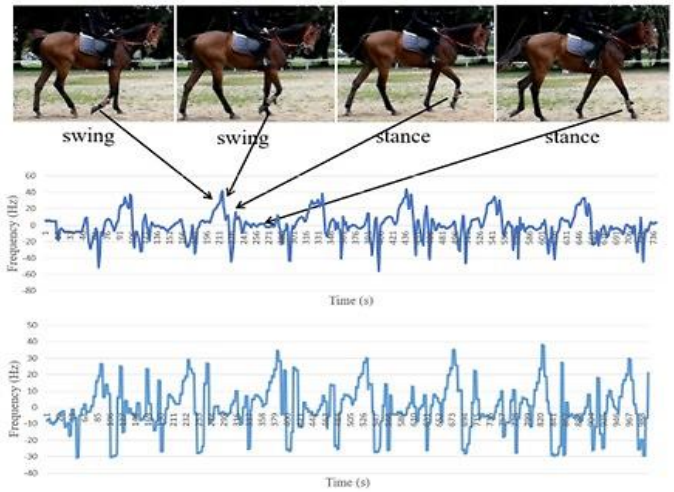
4.2 Correlation analysis

Result in Table 2 shows the correlation coefficient between Androsensor apps and Delsys Trigno sensor for walk, trot, and canter. Movement detection was conducted manually where each movement was detected from the video recording and then refer back to the acceleration graph. The middle cycle (with duration of 5 seconds) of each trial was selected for correlation analysis. This selection is to ensure a complete cycle of gait was selected.

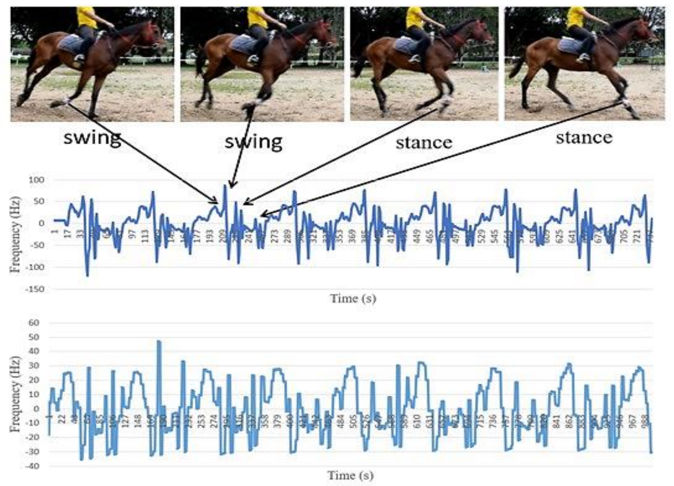
The result shows that gait data captured from all subjects have a higher correlation coefficient ($r>0.5$). It shows that the mobile application has a strong correlation with establish sensor like Delsys Trigno sensor. This result is similar with previous research where it shows that Androsensor apps has a strong correlation with the established devices. Its ability to detect three different gait types will allow the development of new monitoring device for horse gait pattern for endurance event. However, slightly less correlation coefficient stated for walk in trial 1 and 2 for Subject 1 compared to other trials. This might be because of walking direction in the arena changed from clockwise at trial 1 to anti-clockwise in trial 2. The changes in direction and rotation might affects the trajectory detection.



(a)



(b)



(c)

Figure 2. Equine gait pattern (a) walks, (b) trot and (c) canter captured using IMU Delsys Trigno (top) and Androsensor apps (bottom)

Table 2. Correlation coefficient value

Horse	Trial	Gait	Correlation Coefficient (r)
Subject 1	Trial 1	Walk	0.659
		Trot	0.826
		Canter	1.000
	Trial 2	Walk	0.551
		Trot	0.790
		Canter	0.999
Subject 2	Trial 1	Walk	0.977
		Trot	0.920
		Canter	0.902
	Trial 2	Walk	0.719
		Trot	0.999
		Canter	0.949

5. Conclusion

In conclusion, Androsensor mobile application has a strong correlation with the established device. This preliminary study has given an insight the capability of the apps to be used as performance monitoring device for equine sport and research. However, further study is still warranted to evaluate the performance and usability of Androsensor apps as an alternative tool for horse endurance monitoring. With the existence of low-cost device, it will allow horse trainers, owners, or riders to monitor their horse activity for long-distance without following the horse all the way.

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