Validation of the IPOS Gait Detection Algorithm for horses under different field conditions.

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Abstract

Background: Intensity of horse training sessions is typically determined by Riders' perception, which is often not very accurate. Therefore, many riders express the need for measuring actual intensity of their horses' training based on the time they spent in each gait. The IPOS Mobile Phone Application incorporates a machine-learning based algorithm that can do that by automatically detecting gaits during a training using sensors of a smartphone.

Objectives: Validate reliability of the IPOS Gait Detection Algorithm during a number of real-life trainings.

Methods: A total of five Warmblood horses (height > 1,48m) were used during the trial. Data was collected using a smartphone positioned under (1) the lunging girth, (2) a specially designed pocket in the saddle pad and (3) the riders' pocket. Data was collected while subjects were performing standardized trials that were video recorded. Video analyzes was used as the golden reference for determination of the actual gait during a training. The reliability of the computed time per gait was calculated as the difference in seconds between results of the IPOS Gait Detection Algorithm and video analyzes.

Results: On average, the algorithm detected the same gait as observed on the video in 98% of the time. The algorithm performed best in detecting the trot with 99,1% reliability and scored the lowest with 96,8% reliability for the canter. For the three different phone placement positions the reliability numbers were: 98,7% under the lunging girth, 98,5% in the saddle pad and 97,4% in the riders' pocket. A significant difference was seen comparing position under the lunging girth or saddle pad and the riders' pocket (sig. < 0.05). No difference was found between detecting gait from the saddle pad and the lunging girth. No significant difference was found in the reliability detecting the gait in either the left or the right direction (98,2% and 98,4% respectively).

Main limitations: The described algorithm is not tested on horses <1,48m or gaited horses.

Conclusion: The IPOS Gait Detection Algorithm was able to correctly detect the gait 98% of the time. The gait detection was reliable in all three mobile phone placement positions. No significant difference was observed measuring gaits in counterclockwise and clockwise directions.

Introduction

In equestrian sports a range of new technologies have been introduced lately with such examples as tension and pressure recording equipment or heart rate monitors. While remote data loggers have been used for decades, they have entered a new era with availability of smartphone applications (apps) that allow real-time manipulation of data and immediate data capture and analysis *(Randle, 2017).*

Riders' experience of the training sessions does not always match with reality. Therefore, many riders want to know the intensity of their horses' training. The time spent on each gait can be used to calculate the energy expenditure and thus intensity *(Clayton, 1991).* Heart rate equipment is sometimes used for that purpose but has not yet been adopted by mainstream riders due to high price of the technology and the high level of knowledge required to interpret the data *(Munsters, 2013).* Therefore, we believe that measuring and keeping track of training intensity that is made easy and affordable by using off-the-shelf technology is the first step in developing Equestrian sports into a more data driven one. With sufficient data collected by the Riders it will then become possible to analyze data and qualify what is optimal in order to improve performance. In order to reach truly scientific conclusions that lead to relevant performance improvement advices, the recorded measurements and gaits detections need to be accurate and precise. Therefore, statistical analysis of this technology and method is required *(Randle, 2017).*

Several (pilot) studies were performed detecting the gait of a horse with sensor technology. *Braganca (2016)* wrote a new method using IMU sensors, reflective markers on each leg and force plates. Another study determines gait-cycle variables in lame and non-lame dairy cows called the Cow-Gait-Analyzer. The sensors automatically select the relevant gait based on accelerometer data. The algorithm was validated by comparing the accelerometer with the synchronized video data *(Alsaaod, 2017).* It's the validation approach that was also used in this study.

The purpose of the study described in this paper was to evaluate and validate accuracy of the IPOS Gait Detection Algorithm that is used in the IPOS Training Application. The application makes use of the smartphone sensors: accelerometer, gyroscope and magnetic field. An algorithm was developed using generic machine learning technics to determine the gait of a horse: standing still, walk, trot and canter. The algorithm was developed with over 7 million lines of data and trying out more than 120 different features. The data cleaning and feature selection processes led to a set of 7 significantly contributing features based on which the gait of a horse could be characterized.

Raw data collected from sensors of the smartphones require certain level of pre-processing before being used by a higher level algorithms. It is related to the nature of mobile devices that perform multiprocessing and at the same time have limited computational power and battery life. To make sure that the data is suitable and can used into the higher-level algorithms, validation subtasks were included to clean and subsequently process this data *(Pires, 2016).* Only validated data cleaning algorithms and techniques were used to ensure maximum reliability of the results (*Björnsdotter, 2017).*

The IPOS Gait Detection Algorithm was trained on three smartphone placement positions. The validation tests examined if there was a significant difference between the three positions as well as determine any differences in riding on a clockwise (right) or counter-clockwise (left) circle.

Materials and Methods

A total of five Warmblood dressage or showjumping horses (four geldings and one mare) with a height between 1.48–1.80m and age range of 6–22 years were used for this study.

Data collection

All subjects were equipped with a Samsung Galaxy A6 smartphone with Android operating system. Data was collected using the IPOS Data collection application version 0.6.1 and utilizing IPOS Gait Detection Algorithm. Both the raw sensor data as well as the calculated time spent in each gait was collected by the algorithm. The smartphone was positioned under the girth (picture 1) while lunging the horse (Lunge), in a specially designed pocket (picture 2) in the saddle pad (Saddle) or in a small fitting pocket of the rider's jacket (Pocket).

Picture 1: Smartphone under the lunging girth

Picture 2: The saddle pad with a smartphone pocket

Data was collected while subjects were following a standardized trial protocol consisting of standing still (stand), walking (walk), trotting (trot) and cantering (canter) both on the straight line and the circle (20 meters in diameter) either during lunging or ridding (table 1). All trials were performed in a regular horse riding arena with a soft, sand surface. Horses were warmed up for a period of ten minutes before the first trial. 12 minutes of the horses' movement was measured per trial.

Table 1: Standardized protocol per trial

	smartphone position: Lunging girth	
	Gait	**Minutes**
	Stand	1
Left	Walk	1
	Trot	1
	Canter	1
	Trot	1
	Walk	0,5
	Stand	1
Right	Walk	0,5
	Trot	1
	Canter	1
	Trot	1
	Walk	1
	Stand	1

	Smartphone positions: Saddle pad and riders' pocket	
	Gait	**Minutes**
	Stand	1
Straight	Walk	1
	Trot	1
	Canter	1
	Trot	1
	Walk	1
Right	Walk	0,5
	Trot	1
	Canter	1
	Trot	1
Left	Canter	1
	Trot	1
	Walk	1
	Stand	1

Based on literature, the sensors reading was set to a sampling rate of 50-60 Hz (*Cengizhan 2016, Björnsdotter 2017*). Data was stored on the smartphone and was sent to the cloud after each trial.

All trials were video recorded using standard video equipment for retrospective analyzes of the collected data. It was known that the IPOS Data collection application has a delay of a few seconds before it starts collecting data. Therefore, synchronization between smartphone data and the video was done retrospectively, setting the first transition from standing still to walking as a starting point.

IPOS gait detection algorithm

The gaits are determined using 7 mathematically calculated features derived from the accelerometer, gyroscope, and magnetometer sensor data generated by the phones' movement. Features are calculated in a specific consistent data window, within the window, most smartphones produce sensors data at 50 to 60Hz. Lesser quality sensors can have a lower frequency but using interpolation all data is resampled to 50hz. Based on testing under laboratory conditions, it was determined that the algorithm requires three seconds of data in order to detect a pattern and determine the gait.

Data analyzes

Video analyzes was used as the golden reference for gait detection. The reliability of the computed time per gait (standing still, walk, trot and canter) was calculated as the difference in seconds between the IPOS Gait Detection Algorithm and the video analyzes.

The true transition per gait is determined visually by evaluating the foot placement of the horse in the video. The walk is a four beat, the trot a two beat and the canter three beat foot placement. The first change in foot placement is recorded as the start of a new gait. All analyses were performed using Excel 2016 for MacBook and IBM SPSS Software version 24. We used Excel to review and mark if the gait detection of the IPOS Gait Detection Algorithm corresponds with the reality by indicating '0' for faults and '1' for good detections. Later the file was imported into IBM SPSS Software to calculate the percentage of 'good' detections. Descriptive statistics are used to test the reliability of the gait detection and the variance-analyze is used to test the significant difference between the positions and directions. Subsequently, the Least Significant Difference (LSD) test is performed to test differences between the averages.

Results

In total, fourteen trials were performed for data collection. Five trials with the smartphone positioned in lunge girth, five in saddle pad and four in the rider's pocket. In total 9994 seconds of gait measurements have been collected and analyzed.

- **Differentiating gaits**

Table 2 shows that in 98% of the time the gait detected by the application was the same as the gait performed on the video. The standard deviation was low (0,001). This supports the conclusion that the IPOS Gait Detection Algorithm was reliable.

Table 2: Descriptive statistics for gait detection [Mean reliability: 98,2%]

		Statistic	Std. Error
Mean		,98	,001
95% Confidence Interval for Mean	Lower Bound	,98	
	Upper Bound	,98	
5% Trimmed Mean		1,00	
Median		1,00	
Variance		,017	

Table 3 shows the agreement between the application and the video record differentiated by gait. The application performed best in detecting the trot. In 99.1% of the time if trot was detected by the application also trot was being performed in reality. With 96,8% reliability, canter detection performed the worst. In 3.1% of the time the canter was mistakenly characterized as trot. In walk, the algorithm was correct 97,9% of the time. If the algorithm detects walk incorrectly it classified the gait also as trot. Standing still was never mistaken for canter or trot. In 1.2% of the time, the standing still was mistakenly classified as a walk. But still in 98,8% of the time also the classification standing still was mad correctly.

Table 3: Crosstabs percentage within the video record [With 99,1% trot scored best; With 96,8% canter scored worst]

		Algorith				
		Canter	Stand	Trot	Walk	Total
Reality	Canter	96.8%	0.1%	3.1%		100.0%
	Stand		98.8%		1.2%	100.0%
	Trot	0.6%		99.1%	0.3%	100.0%
	Walk		0.2%	2.0%	97.9%	100.0%
Total		20.7%	16.2%	35.9%	27.2%	100.0%

- **Reliability per positions**

Table 4 shows the reliability in different positions of the smartphone. Placing the smartphone under the girth while lunging resulted in the highest gait detection reliability of 98,7%. Putting the smartphone in a pocket in the saddle pad also performed well with a 98,5% reliability. Putting the smartphone in a pocket of the rider's jacket gave the lowest reliability score with a correct detection of gaits in 97,4% of the time.

Table 4: Percentage reliability positions [Mean: Lunging girth: 98,7%; Riders' pocket: 97,4%; Saddle pad: 98,5%]

Placement1	Mean	Std. Error
Lunge	,987	,002
Pocke	,974	,002
Saddle Pad	,985	,002

The Variance-analyze is performed to check if the three smartphone positions contain a significant difference (<0,05). A significant difference (table 5) was seen comparing the position under the girth while lunging the horse or placing the smartphone in the saddle pad with placing the smartphone in the riders' jacket while riding (Significance 0.000). No difference was found between detecting the gait from the saddle pad and the lunging girth (Significance 0,502).

Table 5: Least Significant Difference (LSD) positions [Sig. difference between lunging girth/saddle pad and riders' pocket (<0,05); No sig. difference between lunging girth and saddle pad (>0,05)]

(I) Placement1	(J) Placement1	Mean Difference (I-J)	Std. Error	Sig.
Lunge	Pocke	,01*	,003	,000
	Saddle Pad	,00	,003	,502
Pocke	Lunge	-,01*	,003	,000
	Saddle Pad	-,01*	,003	,000
Saddle Pad	Lunge	,00	,003	,502
	Pocke	,01*	,003	,000

Based on observed means.
The error term is Mean Square(Error) = .017.
*. The mean difference is significant at the ,05 level.

- **Changing directions**

All trials were performed in a straight line, in counter clockwise (left) direction and in clockwise (right) direction. Table 6 shows a similar reliability for detecting the gait in either the left or the right direction (resp. 98,2% and 98,4%). Variance analyzes test showed no significant difference in reliability between both directions.

Table 6: Percentage reliability directions [Mean left: 98,2%; right: 98,4%]

Direction1	Mean	Std. Error
Left	,982	,002
Right	,984	,002

Conclusion

The IPOS gait detection algorithm was able to detect the gait of the horse correctly in 98% of the time. Trot had the highest reliability of 99,1% and canter the lowest with 96,8%.

The gaits were detected reliably in all three mobile phone placement positions: 98.7% with the smartphone under the lunging girth, 98.5% in a saddle pad and 97.4% with the smartphone in rider's pocket.

No significant differences were seen detecting the gait on a counterclockwise direction (left) or clockwise direction (right).

Discussion

The IPOS Gait Detection Algorithm was validated on horses of 1,48m and higher. No smaller ponies and also no gaited horses with gaits such as tölt, Western horses in lope nor racehorses in gallop were part of this trial. Therefore, the same high-reliability scores might not apply to these types of horses and gaits.

Distinguishing between trot and canter was the most difficult for the algorithm. The algorithm has been detecting that horses were performing canter when actually still trotting. It can be explained by looking at the raw accelerometer data that shows that both gaits have similar patterns and that horses vary a lot in the amount of elevation and horizontal displacement in trot and canter. More variation in training data is needed to improve detection of differences between trot and canter. This can be achieved over time.

Maintaining a steady gait was sometimes hard for the horses during a training resulting in a lower reliability score for that specific part of the training. For example, one horse changed the canter with only his hind legs. This resulted in less elevation in the canter. The application detected than trot instead of a mixed left and right lead canter. During standing still, some of the horses were not really standing still and the occasional step back and forward resulted in the algorithm to pick up a walk by mistake.

The algorithm is designed to pick up changes in gait after three seconds of changing riding pattern. This means that small transitions (< 3 seconds) of a couple of steps were not detected by the application and resulted in many 1-seconds errors around the gait transition periods. This was observed for example with a horse falling back to trot during canter for only two strides.

The IPOS Gait Detection Algorithm is trained to recognize movement of a horse from different phone placement positions. However, when the smartphone is positioned in the pocket of a riders' jacket the movement is not the same as on a horse. For example, in trot, the riders were performing rising trot although a sitting trot would correspond better with the fixed position on the horse. We have observed a slightly lower reliability for detecting the gait from the pocket compared to the saddle pad. It might be caused by either the difference in rising and sitting trot or because the smartphone is more fixated in the saddle pad compared to the rider's jacket. Therefore, we concluded that the looser fixation creates more unwanted movement making it harder for the gait to be detected. This was especially experienced with the smartphone under the girth. Since a girth is strapped tight around the horses' thoraces, causing the highest level of fixation.

During this test, no horses were harmed in anyway or sense. None of the horses displayed any signs of discomfort or stress.

Acknowledgement

We would like to thank Henny Holleman from HAS University of Applied Science, 's-Hertogenbosch in assisting with the statistical analyzes.

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