Evaluation of horse's kinematic
(with and without the rider)

Wearable sensors project

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Aim of this study

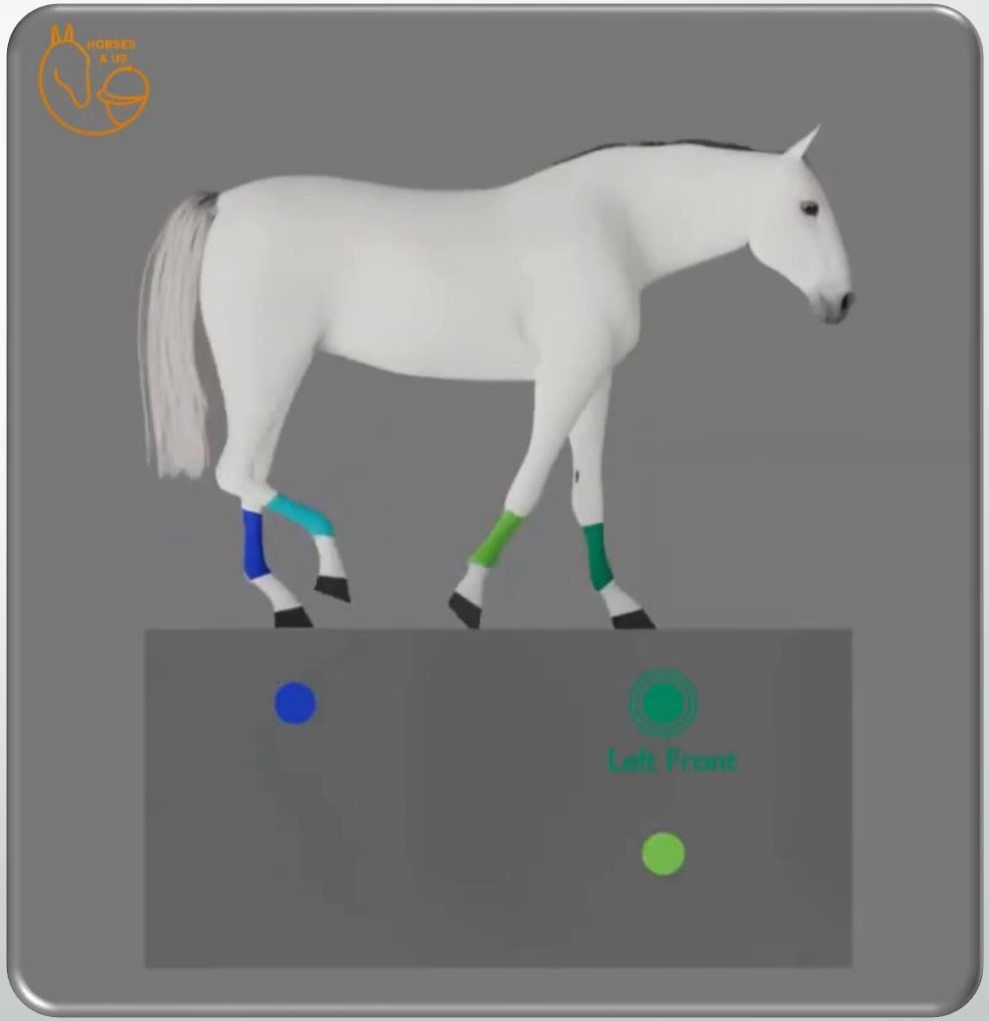
Analyze the kinematic of the equine gaits in different condition

Using accelerometers available in a smartphone

Horse gaits

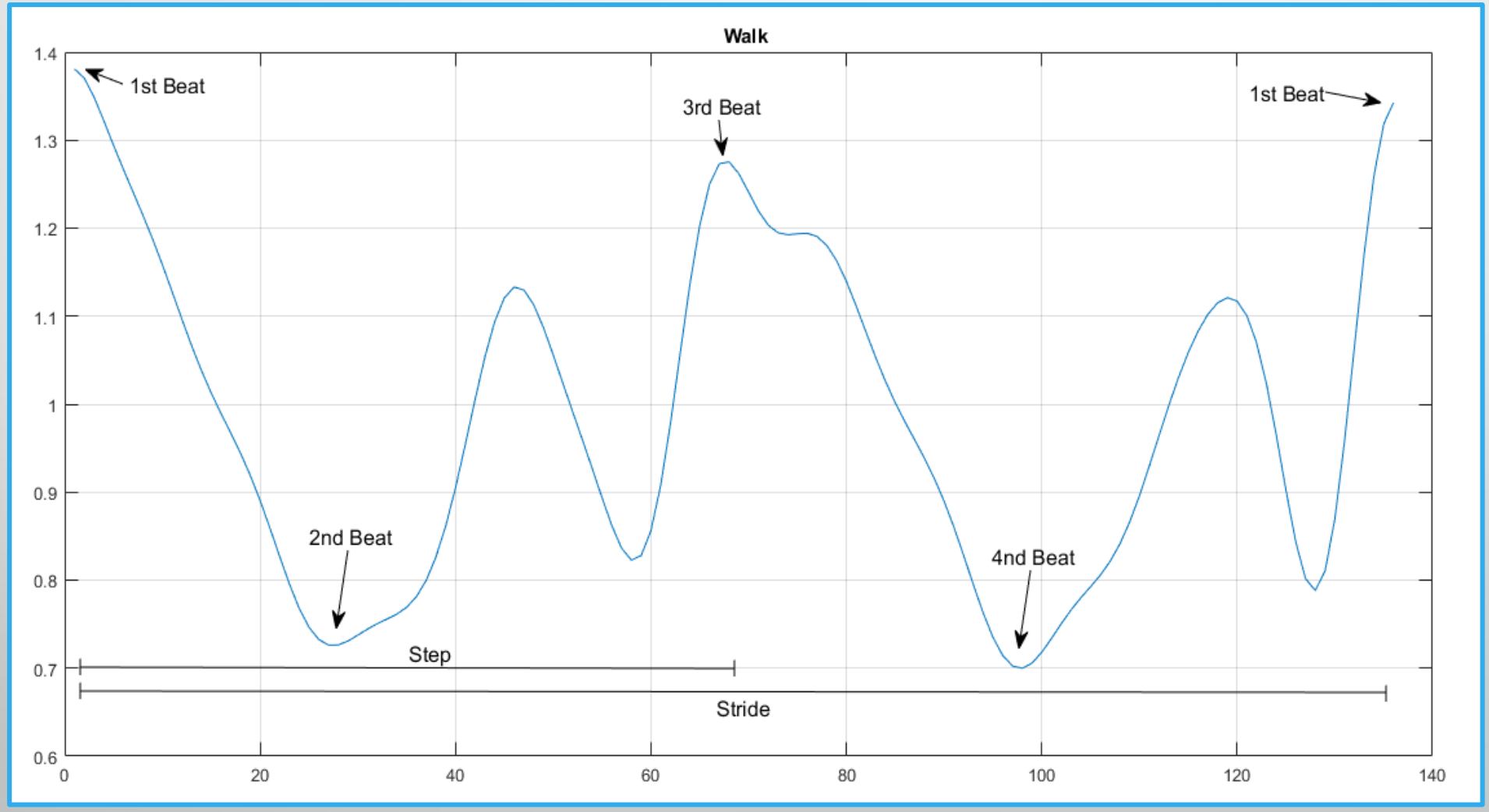
Walk

- It is a slow, **symmetrical 4-beat** gait
- Each hoof hits the ground at a separate interval
- At any moment there are always 2/3 feet on the ground
- The footfall sequence is:
    1. Left Hind (First beat)
    2. Left Front (Second beat)
    3. Right Hind (Third beat)
    4. Right Front (Fourth beat)



Horse gaits

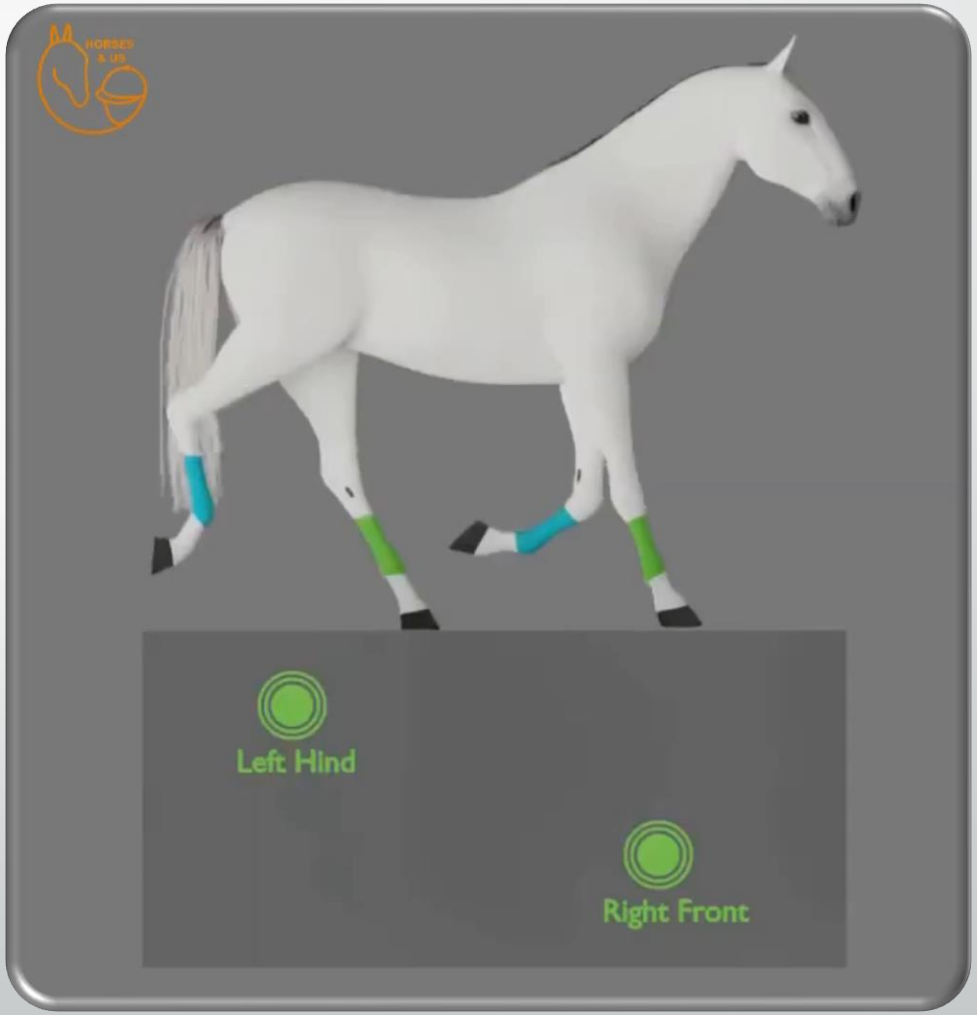
Walk Vertical Acceleration



Horse gaits

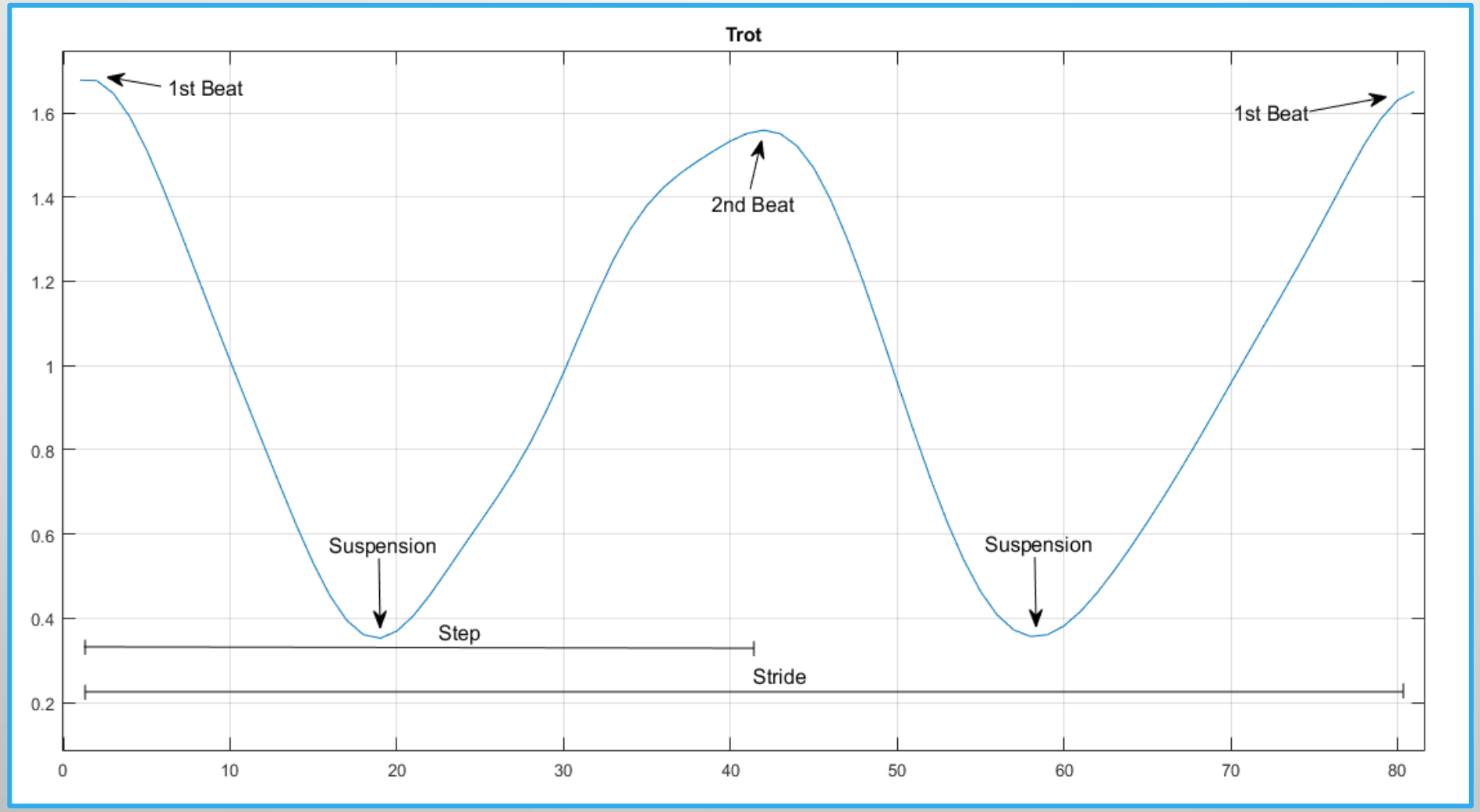
Trot

- It is a fast, **symmetrical 2-beat** diagonal gait
- Each diagonal pair hits the ground at a separate interval, divided by a period of suspension
- At any moment there are either 2 or 0 feet on the ground
- The footfall sequence is:
    1. Left Hind + Right Front (First beat)
    2. Suspension
    3. Right Hind + Left Front (Second beat)
    4. Suspension

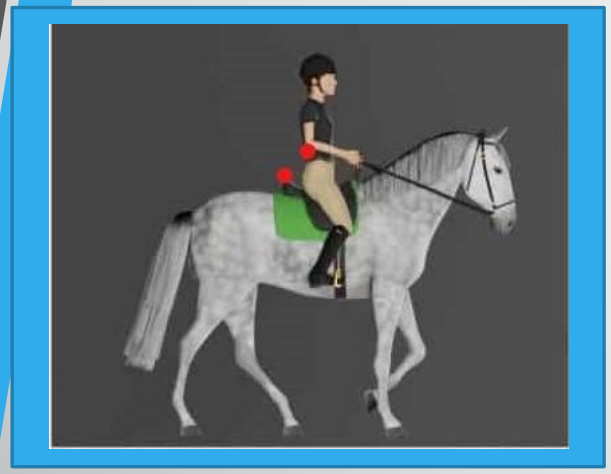


Horse gaits

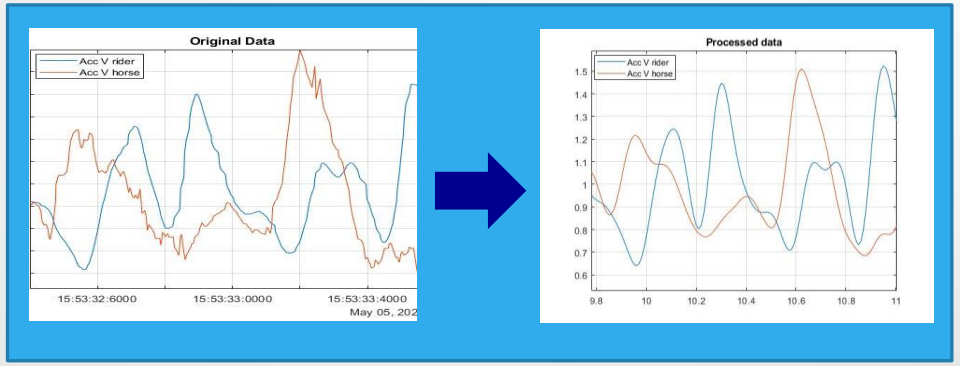
Trot Vertical Acceleration



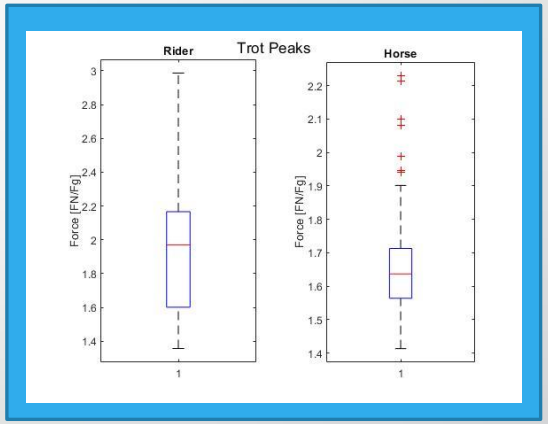
WORKFLOW



1.Data acquisition



2.Data Processing
(Filtering, data cleaning, clustering)



3.Output

1.Data acquisition

- Accelerometers available in a smartphone with 3 degrees of freedom were used.
- Both accelerometers had a variable sampling rate ranging from 198-201 Hz.

1. One accelerometer (LIS2HH max capacity: ±4g) was attached to the rider's pelvis (L3-L4)
2. The other accelerometer (BMA2X2 max capacity: ±16g) was attached on the saddles back.

2.Data Processing

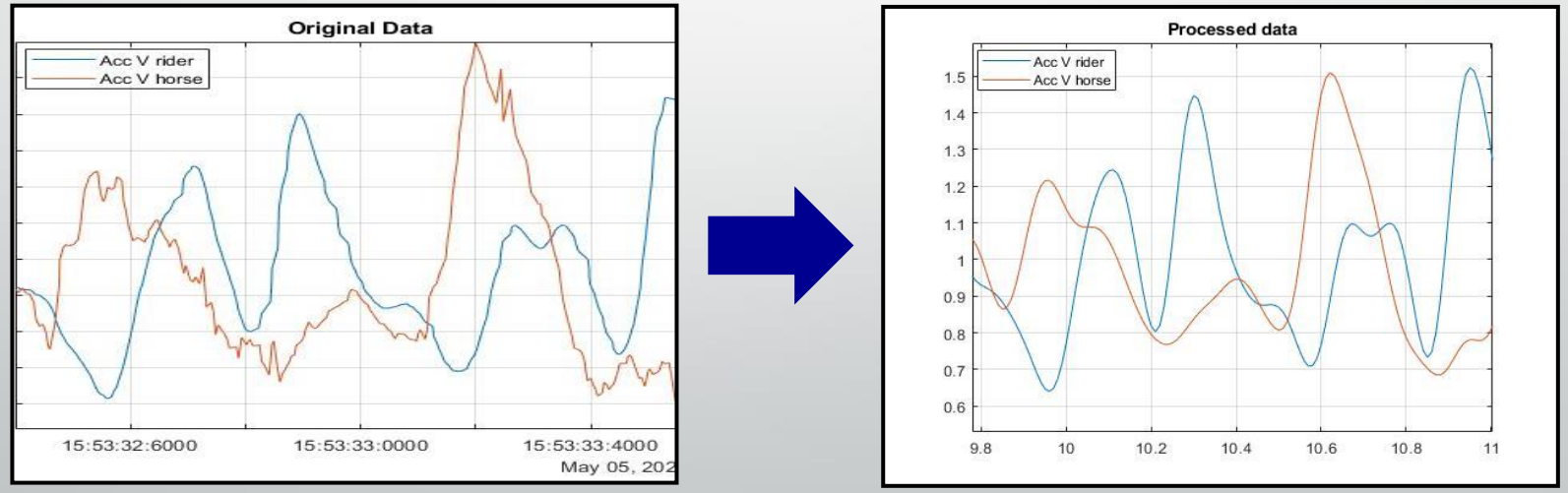
The accelerometers give us a .csv file with 4 columns that contains the three acceleration components and the total force.

Then, the data were transferred to a laptop and processed using MATLAB R2020b.

The data signals were imported from the .csv file into a struct, in order to store and manage more carefully with the data.

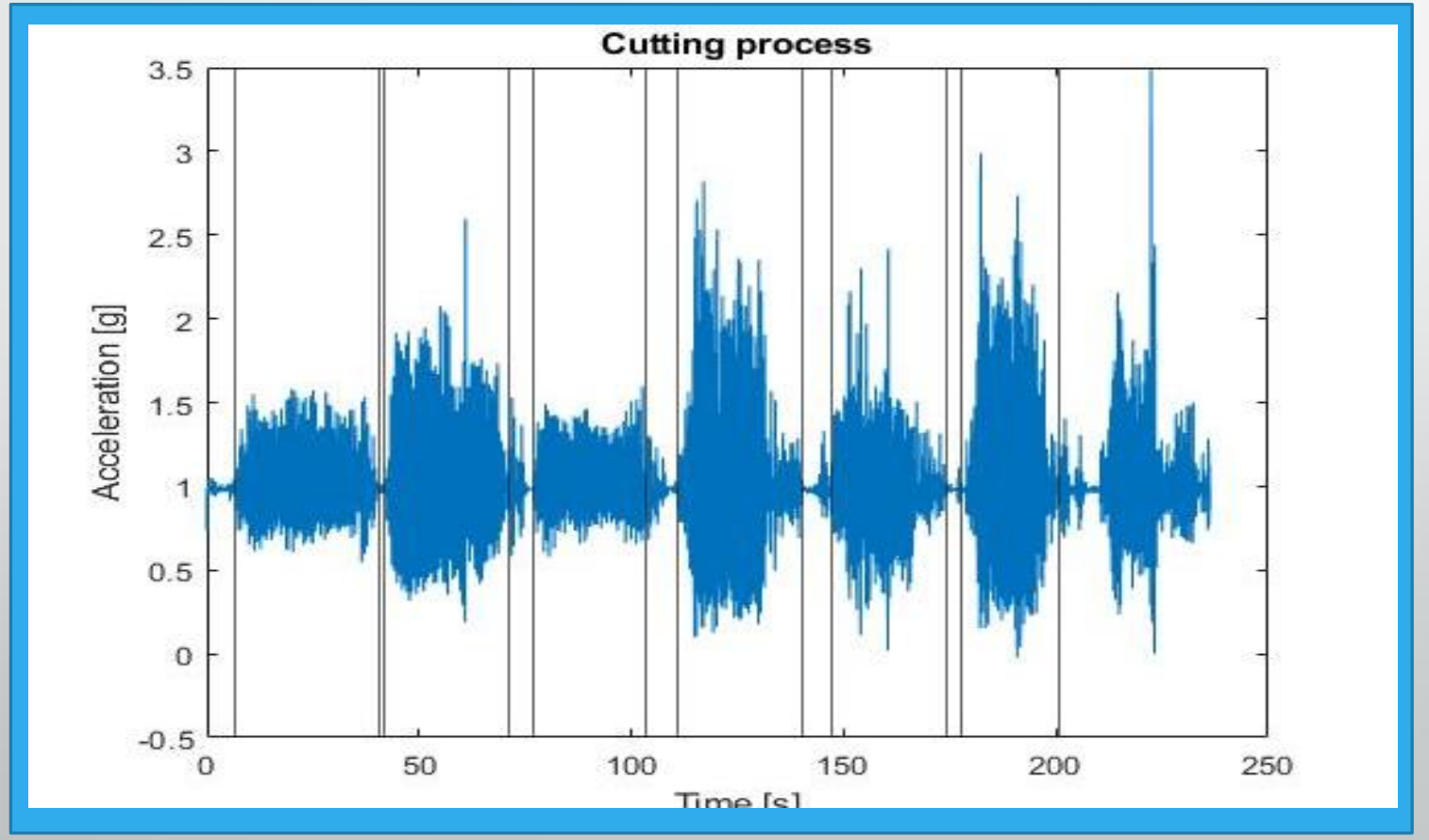
2.Data Processing

- Data resampling at 100 Hz
- Data filtering with a 7-th order Butterworth low-pass filter with a cut-off frequency equals to 10 Hz



2.Data Processing

- Tilt correction using the Moe-Nilssen's algorithm
- Signals' cutting in order to obtain the single sessions of walk/trot



3.Output

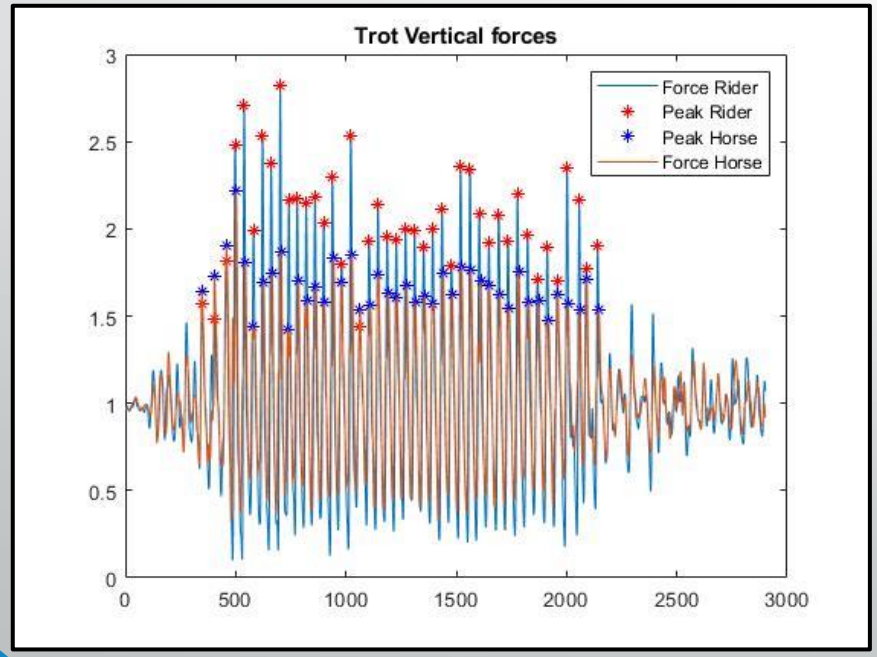
1. Evaluation of total force to which the rider's back is subject
2. Analysis of horse gaits in different condition (evaluation of the rider's acceleration and its relationship with horse's acceleration)
3. Detection of different gaits using a machine learning algorithm

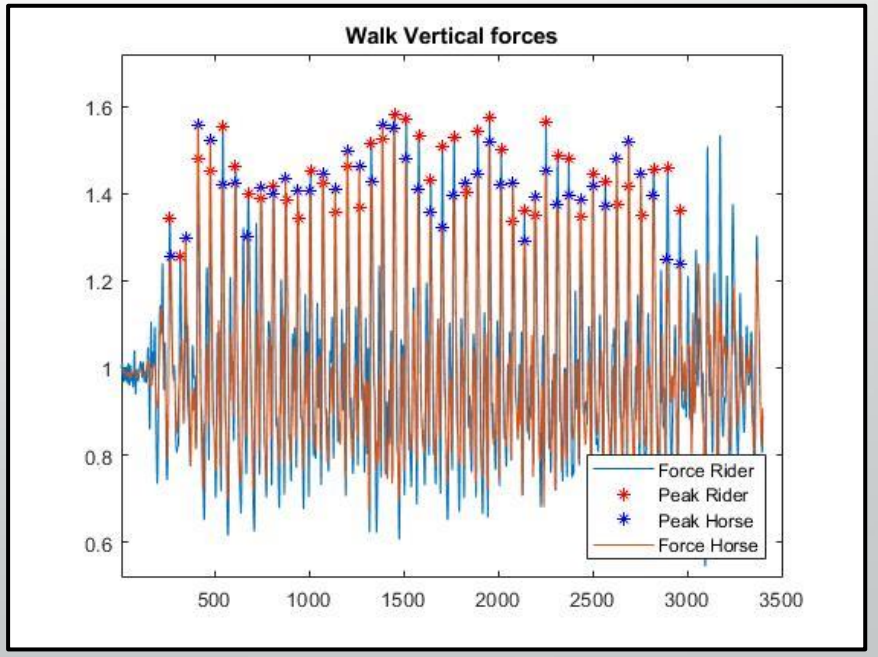
Evaluation of total force on the rider's back

Goal = to establish if there is any statistical difference between the forces recorded on the rider's back and the forces on the horse's saddle.

How to proceed?

- Peak detection and cleaning of the signals, by selecting only the valid gaits for our purpose.





Evaluation of total force on the rider's back

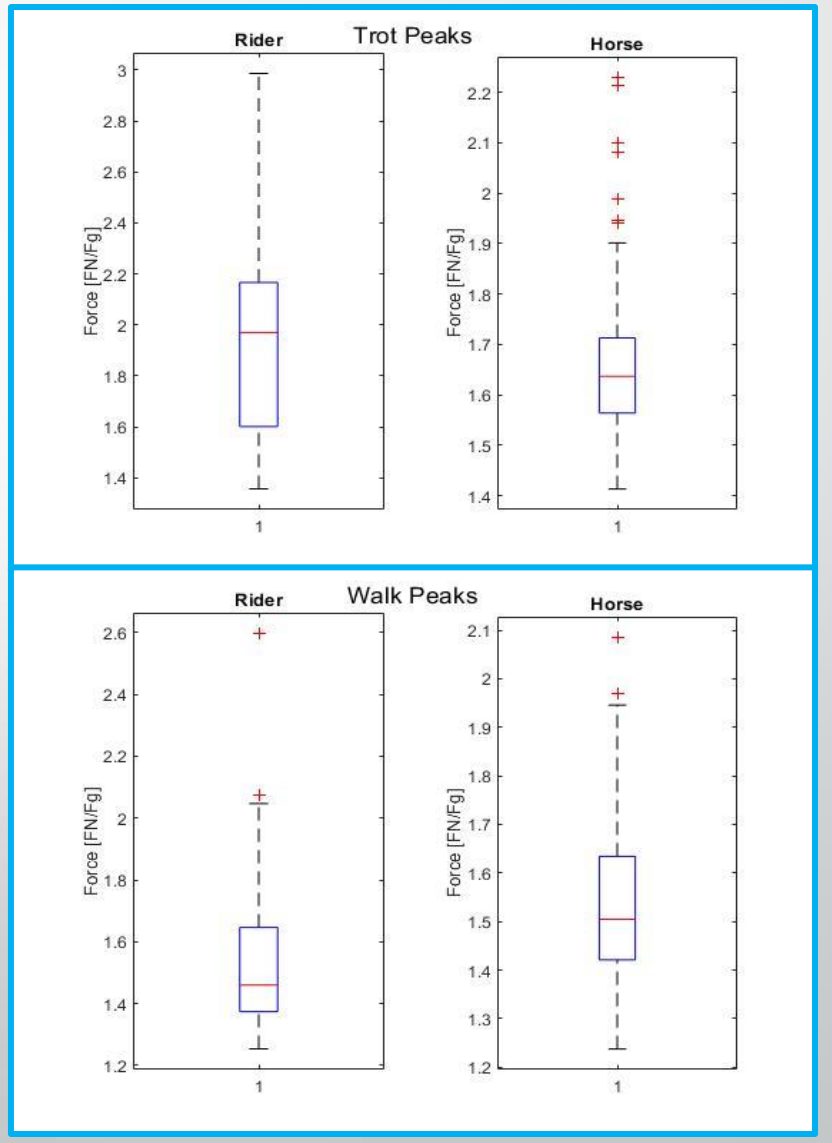
- Some statistical hypothesis tests on the peaks were performed, using a paired non-parametric test (Wilcoxon with sign)

Results:

Only during the trot there is a statistical difference between the horse and the rider (**P-value** = 6.9 e-14).

P-value (walk) = 0.37

This result suggests that during a movement as slow as the walk, the rider and the horse move as a single body , while during trotting the rider is subject to greater forces.

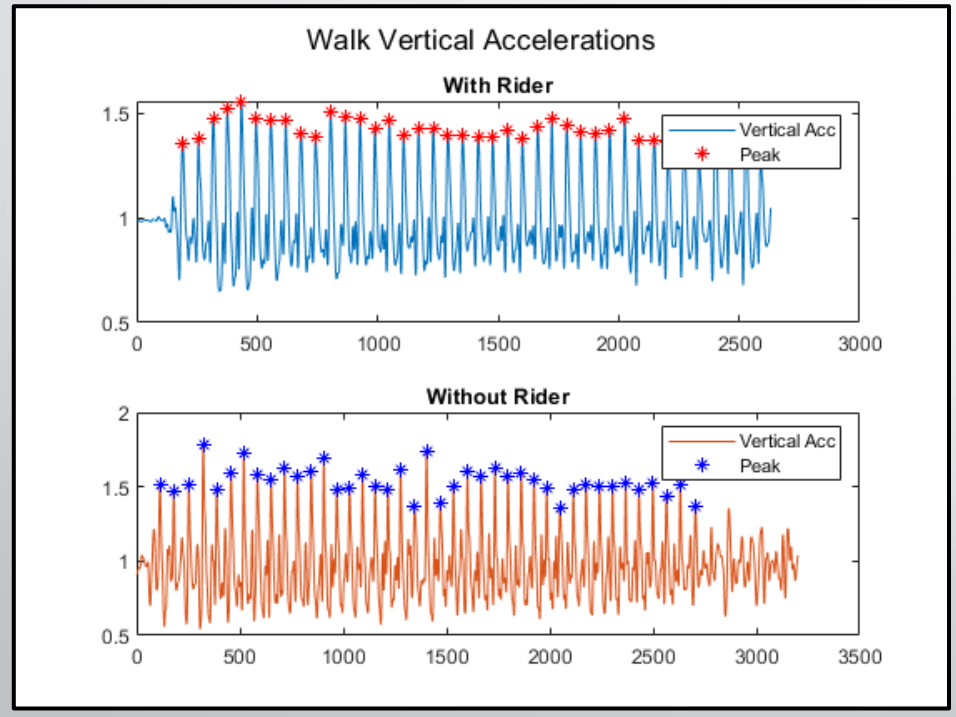


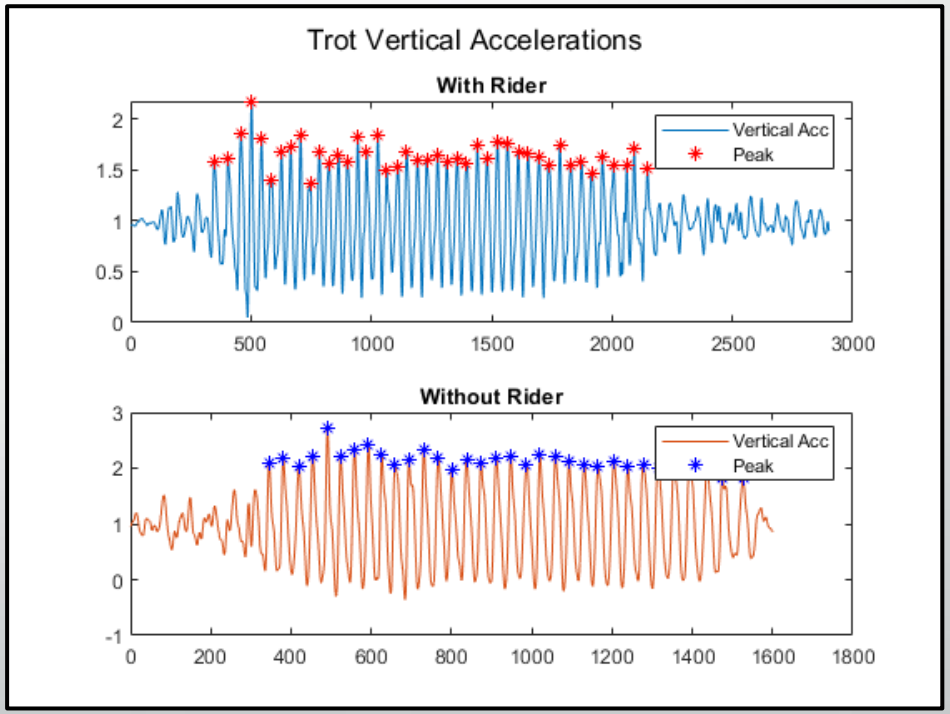
Analysis of horse gaits in different condition

For this research, two different classes of equine gaits (walk and trot) have been studied.

These two gaits have been recorded in two different conditions: with and without rider.

Now some statistics analysis about stride and acceleration peaks can be made.





Analysis of horse gaits in different condition

Gait Peaks

Statistical test: Kolmogorov-Smirnov (not paired non-parametric test)

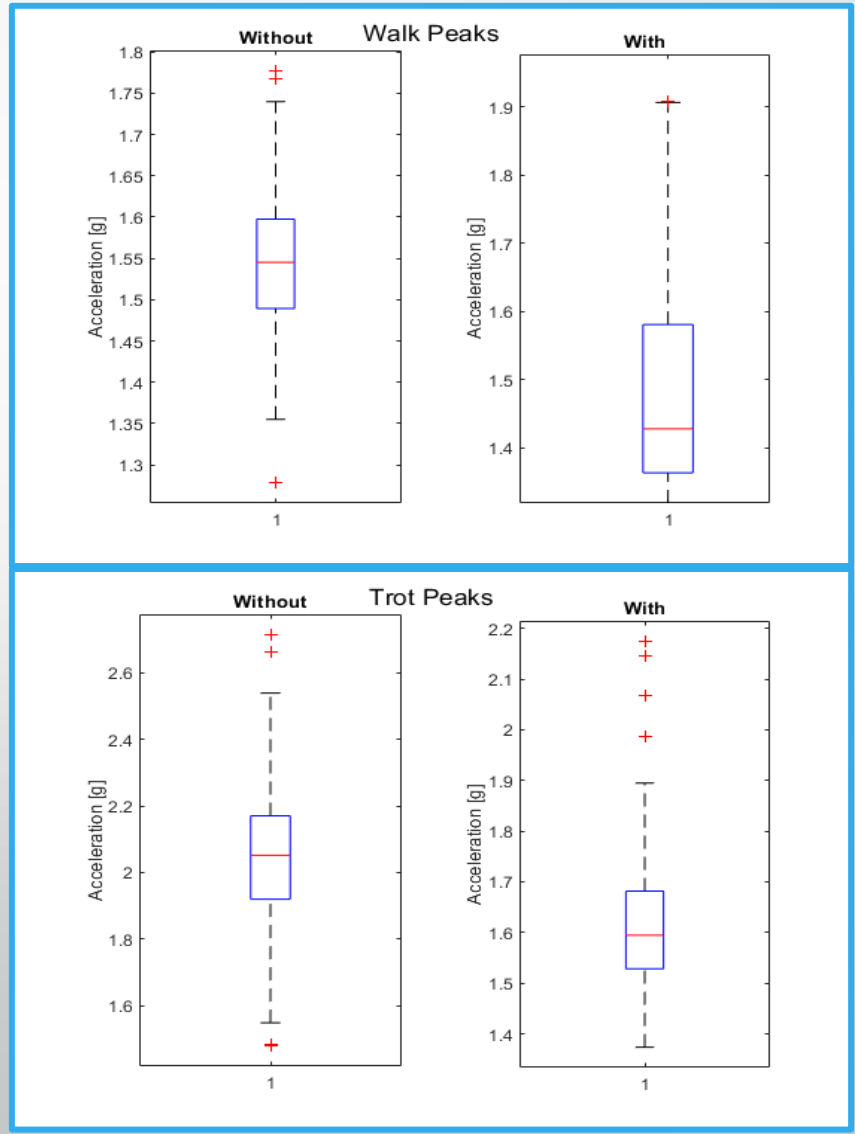
Results

There is a statistical difference between with and without groups of the same gait.

P-value (walk)=6.22e-13

P-value (trot)=3.03e-31

The presence of the rider influences the kinematic of the horse, in fact, the accelerations recorded with the presence of the rider are less than without.



Analysis of horse gaits in different condition

Stride Duration

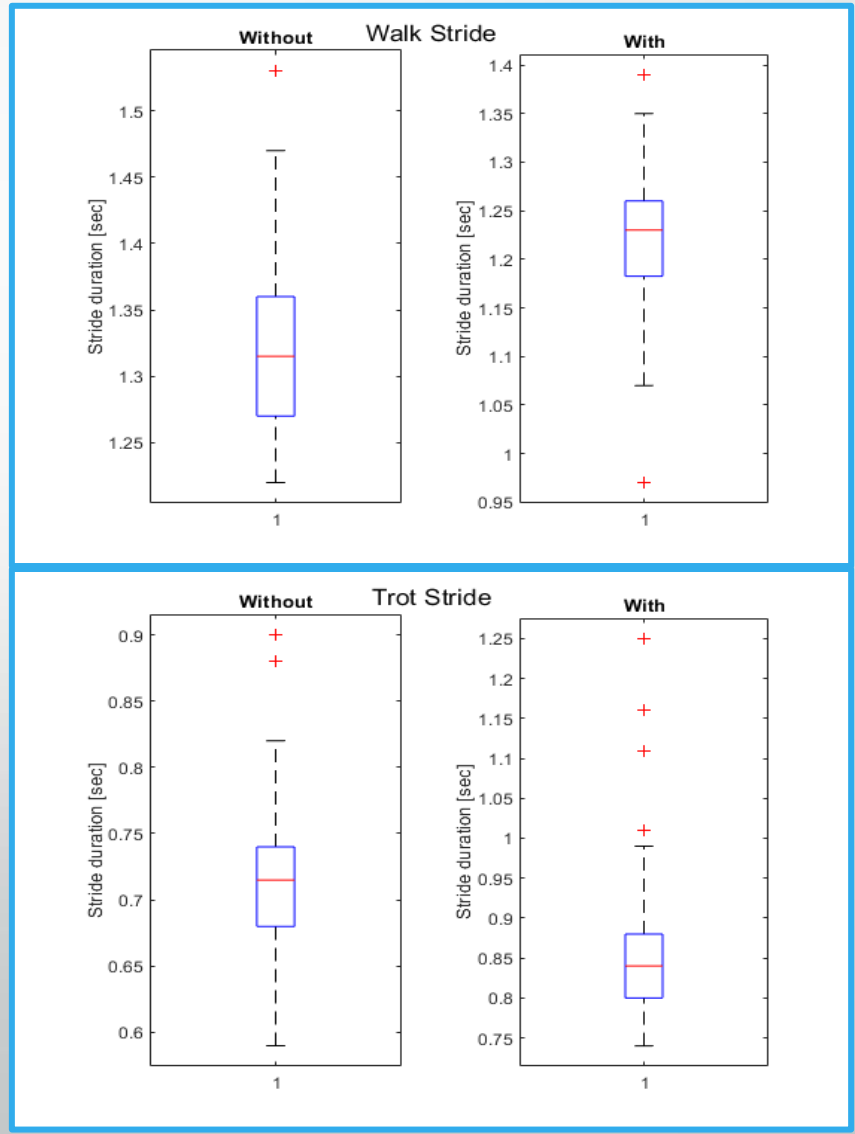
Statistical test: Kolmogorov-Smirnov (not paired non-parametric test)

Results

There is a statistical difference between with and without groups of the same gait.

P-value (walk) = 3.38e-16

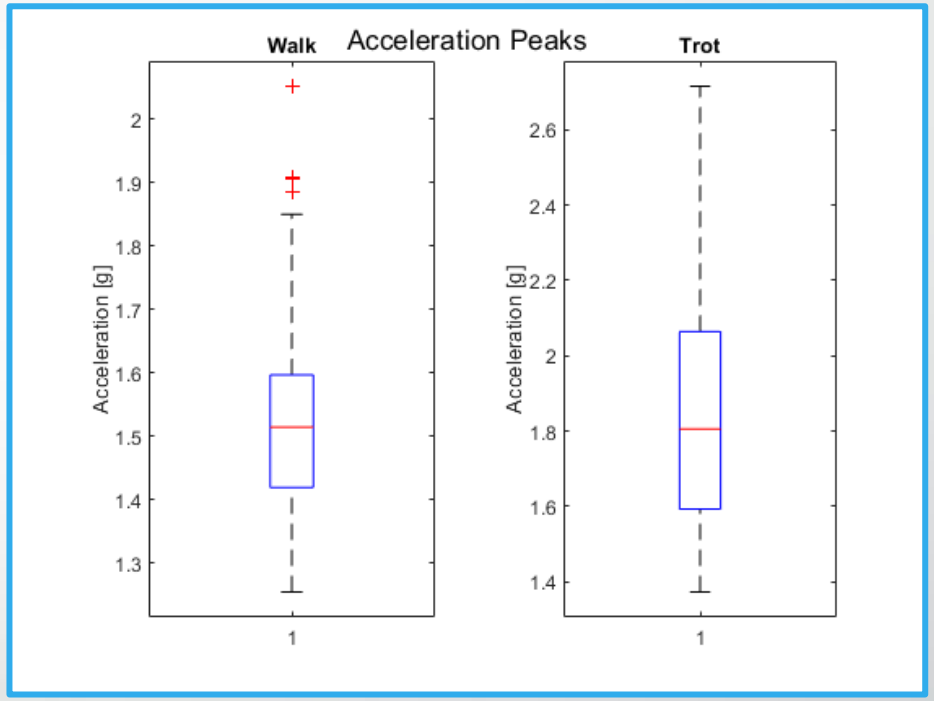
P-value (trot) = 1.63e-09



Analysis of horse gaits in different condition

Acceleration Peaks

Statistical test: Kolmogorov-Smirnov (not paired non-parametric test)



Results

There is a statistical difference between the two horse gaits.

P-value = 6.24e-34

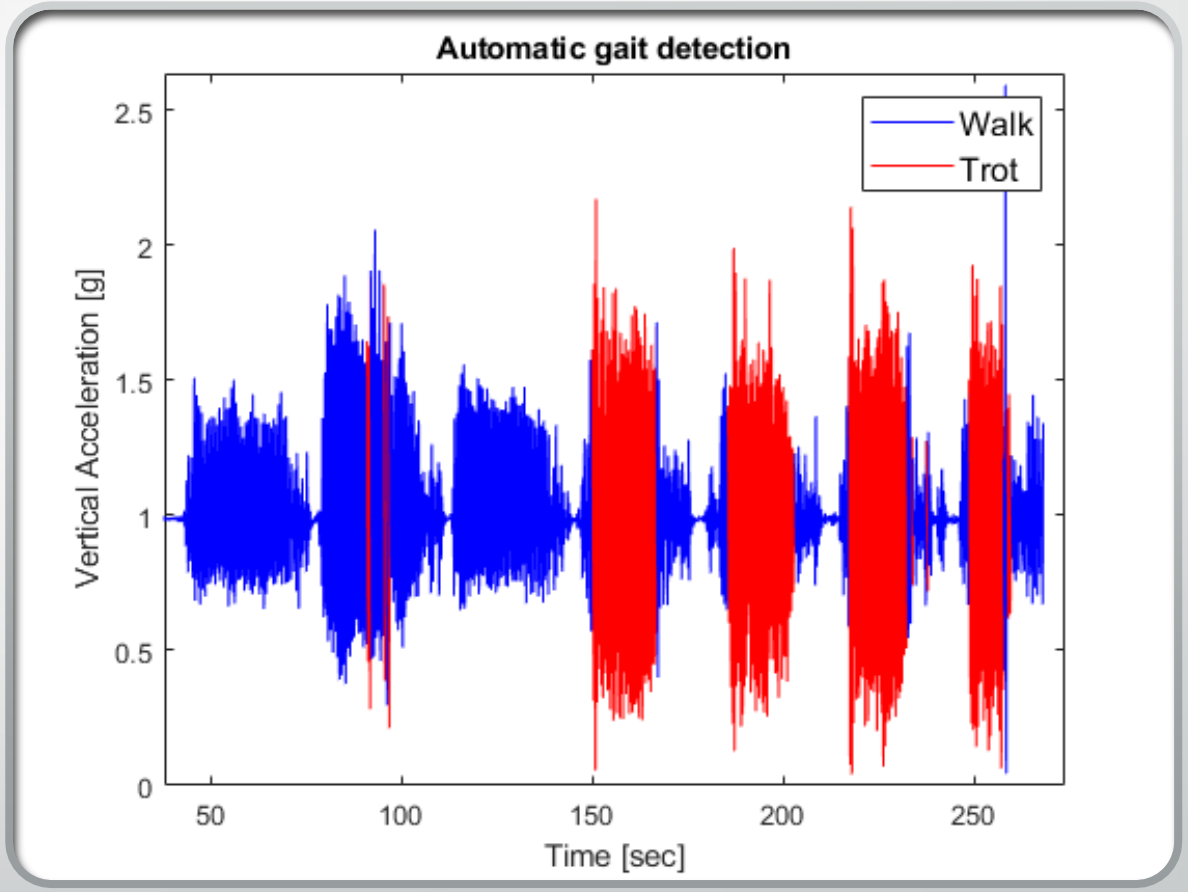
Based on these findings, it is clear that the two horse gaits do not belong to the same population, so it is possible to train a Machine Learning Model in order to detect them (regardless of the presence of the rider).

Detect different gaits

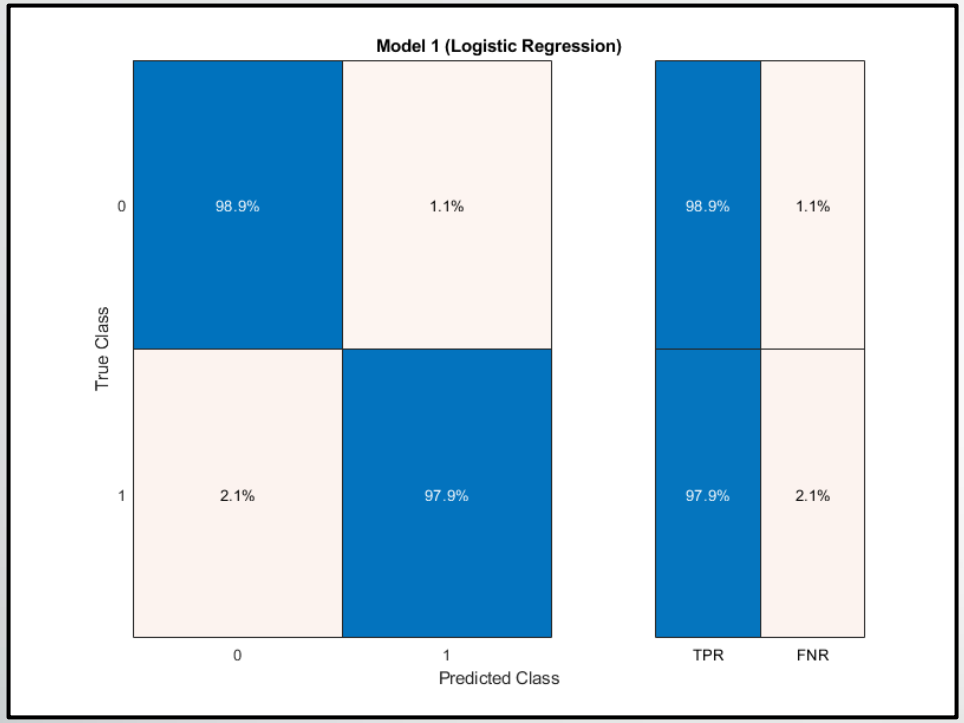
(Using a Machine Learning Model)

The machine learning model is generated using the Classification Learner Toolbox with:

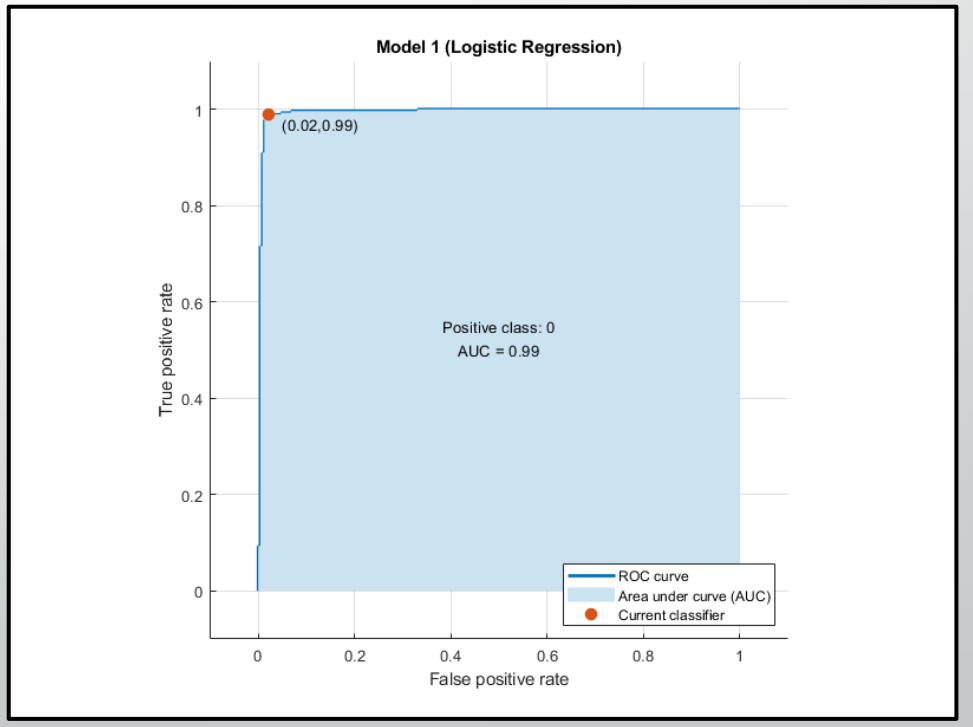
- **Four features**: Vertical acceleration peaks, Step Duration, Kurtosis and Sweness (the last two are calculated over the step duration)
- **Cross validation folds**: ten
- **Classifier**: logistic regression



Machine Learning training



Using only 514 measurements of the four features we obtain an impressive results



The model has an accuracy of 98.4%

With an AUC≈1 the test is highly accurate

Conclusion

Evaluation of total force on the rider's back	Only during trot there is a statistical difference between the horse and the rider
Analysis of horse gaits in different conditions	The two horse gaits do not belong to the same population (regardless of the presence of the rider).
Machine Learning Model	Practical tool to evaluate new recorded signals

Thanks for the attention