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Analysis of a horse simulator's locomotion by inertial sensors

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1. Introduction

To determine the imbalance of each, horse or rider, the balance's quality of the rider will be expertise and improve by an adjusted simulator, without the unpredictable reactions of a real horse. The use of an equestrian simulator enables the rider to improve his technique without the different risks linked to the practice on a real horse. These simulators are sold without any specification regarding the operation, validity and regularity. Such a device has to be however controlled in terms of movement stability (Mager-Maury et al. 2012). This study aims to verify this aspect on a mechanical horse by using an inertial measurement unit (IMU), in order to improve the rider's training programs by adapting the different protocols to the inter-individual differences between the riders. This will allow us to be relevant to the session's repeatability and riders monitoring. The unpredictable reactions of a real horse prevent the accuracy and secure rider's balance studies. The weight and rider's experience has an effect on the horse's behaviour (Clayton 1997; Eckardt et al. 2014).

2. Methods

2.1. Material

A wireless IMU Axivity WAX9 was placed on an equestrian simulator (Peteris Klavins) with a Leroy Somer potentiometer regulated in terms of percentage of the maximal frequency (0–100%) enabled by the 0.37 kW permanent magnet motor. He operates over the range from 0 to 3000 cyc/min, and reduced by a device at 150 cyc/min. The mechanical horse, supplied by an electrical outlet, was equipped with a package enabling to fix solidly and correctly the IMU. The package is fixed under the saddle place, exactly under the projection of the rider's center of pressure. The IMU, set with the acquisition frequency of 200 Hz, was connected by Bluetooth Low Energy with a computer. A computerized processing program was made in order to treat in streaming the recorded data. This program (Scilab software) aimed to recover the data while IMU operating, in order to calculate the mean operating frequency of the simulator by realizing a spectral analysis (Fast Fourier Transformation), to update the processing and to extract the results in a spreadsheet file. The computerized processing program was set in order to treat 2048 lines of data per processing loop. An updating latency of 5 seconds between the processing loops let enough time to the IMU to record new data in order to update correctly the processing.

2.2. Procedure

First way, the regulator's scale was modified by corresponding the percentage to a real frequency in Hertz. The measures extend for this experiment was between 50 and 100%. Under 50%, the simulator's operation was too low to correspond to a real horse's displacement and too low for an adequate engine's couple. We established a correspondence mapping (Figure 1).

Second way, the mechanical horse was set in operation with different frequencies (1.0–2.2 Hz with a 0.4 Hz-increment) were added to the simulator. The real extend frequency band is 1–2 Hz (Barrey and Galloux 1995; Biau 2017). For each frequency, the horse was added different additional inert charges (50–90 kg with a 10 kg-increment). They were located right on the saddle's place with girths. In addition, a test was realized at 1.0 Hz without additional charge in order to establish the differences in behaviour between the conditions with or without additional charge. For each condition, 20 measurements were realized by using the computerized processing program giving the frequency calculated according to the three axes per measurement.
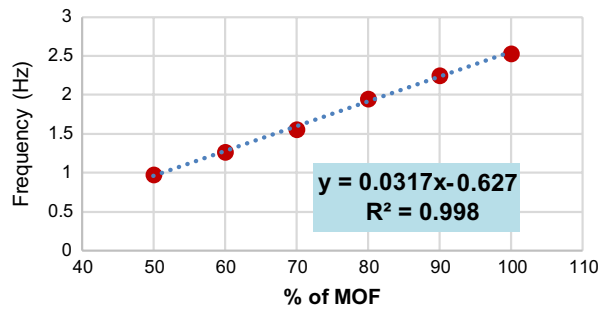
Figure 1. Relation between the measuring scales.

Figure 2. Acceleration for a 70 kg load and at 1.8 Hz.

The results were analysed by means of statistic tests. Normal distribution was not verified with a Shapiro-Wilk test, therefore a non-parametric test of Kruskal-Wallis and a Friedman bidirectional multiple assimilation was realized in order to establish the significance of the differences observed.

3. Results and discussion

The corresponding values of operating real frequencies regarding to the percentage of maximal operating frequency are shown in Figure 1. The stability and symmetry with loads are shown in Figure 2. The statistics analyses are calculated at 10^{-2}, even though the regulator enabled a 10^{-1} accuracy to show frequencies values.

The Kruskal-Wallis and Friedman non-parametric test demonstrates one significant difference (p=0.001) at 1.4 Hz for a difference of 20 kg between 50 and 70 kg. The clearest differences appear at the frequency of 1.8 Hz ($p < 0.001$), for which the mechanical horse's behaviour is affected by a 20-kg difference in additional charge. Those findings demonstrate that inert charge can impact the mechanical horse's behaviour, notably for differences of more than 20 kg (only valid around 1.8 Hz).

The load amount increases the operating simulator frequency (from 1.75 ± 0.01 Hz with a load of 50 kg to 1.85 ± 0.00 Hz with a load of 90 kg). We could have expected the opposite, which means, the decrease in the frequency associated with the inertia of the system.

The value of 70 kg is the hinge value which determines the frequency change as a function of the load. Below 70 kg the horse is stable with a frequency of 1.77 ± 0.03Hz and above it is stable at the frequency of 1.85 Hz. On the other hand, for all other frequencies and the different additional inert charges (50–90 kg with a 10-kg increment) the simulator is perfectly stable.

The operation of the mechanical horse seems more stable in the peak load values in general. The massless curve shows irregular variations in the acceleration as a function of time, whereas the sinu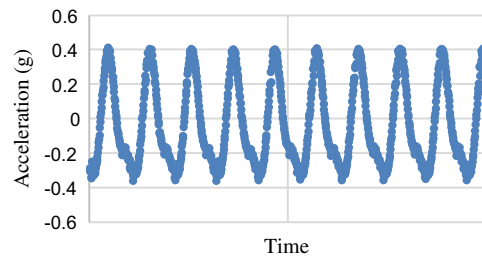soidal aspect is more respected on the curve with the inert charge (Figure 2). The stable operating frequencies for our future study's repeatability were listed. We know the alteration and can take it into account, and if a rider allows a work on a frequencies alteration that will be depend on his own pattern and his weight.

4. Conclusions

To our knowledge, no previous study aimed to analyse an equestrian simulator's stability by using an IMU, adding different charges during move. If the simulator's stability is not effective with a rider, we can conclude that the rider adversely influences the simulator and deduces from his poor dynamic's balance quality. This IMU instrumented horse aimed to be used to validate rider's devices or equine research. It's the choice for creation 'help to the diagnosis of the rider balance' (ADPC) validation. It's a stabilometric saddle platform registred by KHP INT LTD to number 07469216.

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