Horse Lameness Estimator Using Inertial Sensors

Vinícius Betim Guimarães, Marcelo Romanssini and Alessandro Girardi
Computer Architecture and Microelectronics Group - GAMA
Federal University of Pampa - UNIPAMPA
Alegrete, Brazil
viniciusguimaraes.aluno@unipampa.edu.br

***Abstract*—The identification of lameness is a very relevant area with regard to horses, and one of the main problems faced by veterinarians and people who live with these animals daily. The problem is that the identification of lameness is often performed visually, which delays its diagnosis, or it is done by complex systems that make it difficult to implement it to a wide audience and to test a significant number of horses. This paper aims to present the design of a lameness estimator in horses using inertial sensors (accelerometers and gyroscopes). The technique is to use inertial sensors on the animal's head, limb, and pelvis, work with the data that these sensors capture during the horse's movement, and thus be able to carry out a study of the horse's biomechanical movement. Results showed good accuracy in estimating the displacement of the head and pelvis, which limb is injured (left, right), and an easy-to-use graphical interface of the program with the necessary information for the user. The use of inertial sensors demonstrated to be a very useful tool when it comes to identifying lameness in horses.**

***Index Terms*—lameness, sensor, horses, accelerometer, gyroscopic, program.**

I. Introduction

One of the serious problems faced by veterinarians in reference to horses is lameness, being the most frequent dysfunction in horses [1], essentially when it comes to racing animals. Furthermore, it is also the most economically important medical condition affecting horses [2].

Lameness in horses occurs when the animal, in this case, the horse, demonstrates some disturbance of the locomotor system, which can be displayed in various ways when the animal has an injury, for example, on the limb, and it starts to limp.

This lesion is identified, in most cases, from the observation of changes in posture and locomotion of the animal [3]. Experienced and knowledgeable veterinarians are able to identify the animal's abnormal biomechanical movement and conclude whether or not the horse is injured [4].

However, even if the veterinarian has the qualities and abilities to visually detect this disruption of the animal's normal movement, it is because it is already at an advanced stage since there are limitations of the human eye in the perception of asymmetry [5] or even thoughtful specialists differ in the diagnosis [6]–[8].

Consequently, the later an injury is detected, the more serious it gets and the longer it takes to treat it. In addition, when the horse has lameness, walking can cause a lot of pain and discomfort for the animal. As a result, a system that makes it possible to identify this lameness before presenting a change in the posture and locomotion of the horse would be important for professionals in the area, but also for the animal, since it would reduce its suffering. It is worth noting that this detection and diagnosis when related to competition horses is even more critical.

There are several ways to analyze the biomechanical movement of a horse, for example, Optical Motion Capture(OMC), in 3D connected with high-speed infrared cameras [9] or with the use of an inertial sensor on the thoracic spinous processes (the withers) of the horse, in conjunction with optical motion capture cameras [10]. However, these identification systems are quite complex and require, first of all, a high financial investment, in addition to requiring an adequate infrastructure and having a very complex implementation.

For this reason, the proposal of the prototype that is presented in this article is to use only three inertial sensors [11] to observe the equine movement, These sensors will communicate with a computer and inform the user of the necessary information.

Therefore, this paper presents the objective and system proposed by the project, the inertial sensor used, the integration techniques to arrive at the results, the logic of the code and how the displacement amplitude of the animal's head and pelvis is calculated. As well as the identification of the limb (left and right), the application interface and the information that is made available to the user.

II. Development

A. Project's goal

The objective of the project is to develop a lameness system in horses, based on 3 inertial sensors, that is, the accelerometer will be the main device for capturing the equine's movements.

In addition, the project proposal is to develop a low-cost system, thus allowing veterinary offices, breeders, athletes, students, and universities that work with horses daily, to have access to a tool like this. Otherwise, the idea is also to develop a system that is easy to use and implement by the end user, but also has great accuracy, since the objective is to get the lameness to be identified before it is visually noticed, in other words, to detect asymmetries in the orders millimeters and centimeters.

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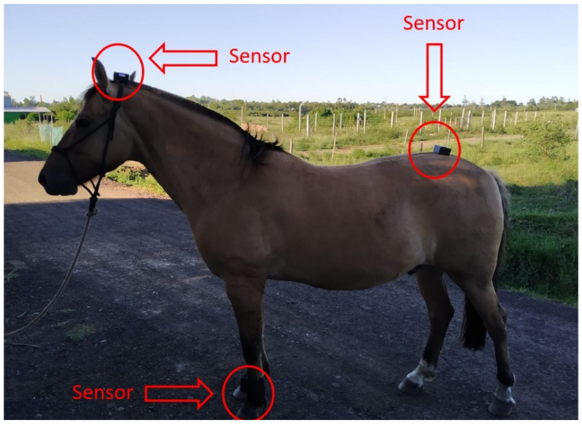

Fig. 1: Image of the proposed system. Inertial devices on the head, limb, and pelvis.

Fig. 2: Image of the proposed system. Inertial devices on the head, limb, and pelvis.

B. Proposed system

The system proposed by the project consists of using two accelerometers and one gyroscope to capture data on the horse's movement. One accelerometer is placed on the animal's head and another on the topo of the pelvis. The gyroscope is fixed in the right front limb, as shown in Fig.1 and Fig.2. These devices communicate with a computer via WiFi, and an application captures the data during the desired period and thus process it (Fig.3).

After saving the data, they are analyzed by a code that works with this information of the accelerations as a function of time and performs the integration of these data, in order to find the displacement of head and pelvis as a function of time. Fig.7. The method to calculate the displacement through the inertial sensor is by performing the integration in the frequency domain [12].

It is important to highlight some points to obtain the data correctly. In the first place, the inertial devices that are placed on the horse (head, pelvis, and limb) must be well fixed so that they do not move, as any movement other than the horse's mobility will interfere with the final results, as well as any friction occurred by the accelerometer and the animal's skin can cause noise in the data obtained and consequently interfere in the data processing process.

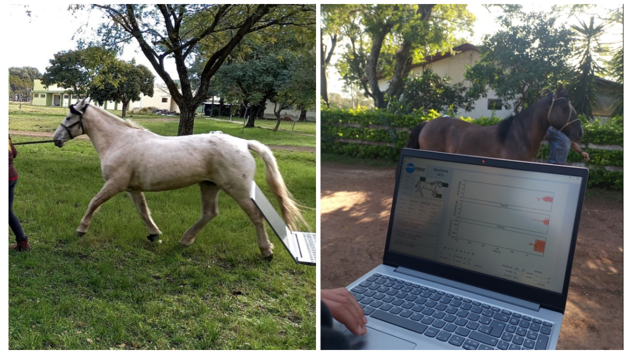

Fig. 3: Image of obtaining the horse's movement data .

Secondly, the procedure to capture the data consists, after placing the devices in the respective points of the horse, making it perform 50 meters trots, 4 times, on a terrain preferably flat and smooth, so that the horse can perform a "clean" and as natural movement as possible, as shown in Fig.3.

The used inertial device is a MuvBox that has the following characteristics: 6 DOF, 3-axis accelerometer, and 3-axis gyroscope. It is powered by a battery and has Wifi for a maximum range of 150 meters and has the ability to capture data with up to 3000 Hz acquisition rate.

III. Head and pelvis displacement calculation

A. Calculation of Diffs

The process of identifying possible lameness in a horse is by calculating the range of motion of the head and pelvis in the z-axis (vertical axis with respect to the ground). When the animal has an injured limb, for example, one of the front limbs, the range of movement of the animal's head and pelvis is different, that is, because one of the legs is injured, the horse tends to support its weight in the "good" limb, causing a movement of divergent amplitude of the head in relation to each limb. An analogous idea is applied to the hind limbs, however, the pelvis is used as a reference in this case.

When the horse is requested to trot to capture the data, the result found from both the head and pelvis accelerometers is a periodic movement similar to a sinusoid (Fig.8). An important point to notice is that each crest of the wave represents one of the limbs and, consequently, the following valley represents a movement belonging to the same limb.

So, for the sake of clarity, when one crest represents the right limb, the next crest will represent the left limb. This identification is made through the inertial sensor that is placed on the animal's limb with the aid of the gyroscope.

The difference between the crests (right and left) is called DIFF MAX HEAD, which is the difference in maximum head height that occurs before weight bearing (right front limb) compared to before weight bearing (left front limb). An analogous idea is applied to the valleys, however, the valleys are used and this difference is called DIFF MIN HEAD.

This calculation of the difference between valley and crests is necessary because when the horse is healthy, the amplitudes

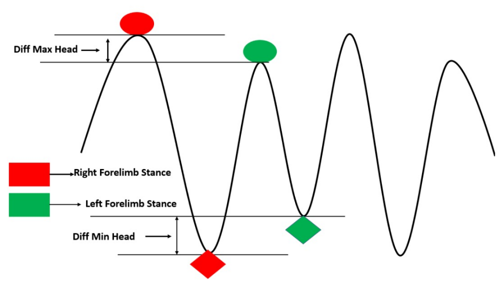

Fig. 4: Head Height Vs. Time in Stride.

of movements of both crests and valley will be equal or will present a very small difference, this will cause DIFF MIN HEAD and DIFF MAX HEAD values to be zero or very small. However, when there is a possible injury to one of the limbs and thus a possible lameness, the animal will end up supporting its weight considerably more on one of the limbs, which will result in a different amplitude of the valleys and crests and thus identify a lameness through the calculations of the DIFFS, which in this way will present a significant value (Fig.4).

IV. Program Interface and Results

In this section, some of the results found by the project are presented, applying the integration process in the frequency domain and calculating the Diffs Min and Max for both the head and the pelvis. To represent the information on the movement of the head, a different view from that of the pelvis is used, since the first concerns the front limbs and the second is with the hind limbs.

The first display for the user is the graph that has the name Forelimb Strides. This display represents information from the front limbs, using the combination of the head and limb inertial sensor. To apply this representation, the Diffs are calculated as previously demonstrated and a vector is calculated using the Max and Min Diffs, selecting the Diff Min on the y-axis and the Diff Max on the x-axis. After selecting the Diffs and placing them respectively on the x and y axes correctly, we use the Pythagorean theorem to calculate the vector.

Performing this procedure for all Diffs, the result found and that will be presented to the user in the application is shown in Fig.5. This representation contains all the calculated Diffs (vectors in blue) and the average of all the Diffs (red vector) and they end up being arranged in a way that in the direction of the positive y-axis represents the direct lameness and the negative y-axis the left lameness.

Analyzing the arrangement of the blue vectors and essentially the red one, the user will be able to conclude in which of the front limbs there is lameness. As an example, if the red vector (average of all vectors) has its arrangement in the positive direction of the y-axis, then it is possible to have a possible lameness of the right front paw.

Investigating the representation of hind limb strides data (pelvis information) (Fig.6), it is worth highlighting the following points: the graph on the left is the representation of what concerns the left hind limb and the one on the right represents the right hind limb. In red are the Diff Max values and in green are the Diff Min values and in the X coordinate axis, the steps in which that Diff Max or Min was performed.

These vectors have the function of expressing the impulse or impact of the limb in each respective step. When it has a red display (Diff Max) it means a pushing movement or that the limb is ”pushing” the ground. However, when there is a green vector (Diff MIn) it means that the respective limb is in impact lameness. It is worth noting that it is possible to have a vector of impulsion and impact in the same step.

To identify a possible anomaly or lameness in the hind limb strides chart, it is necessary to analyze the two representations (left and right hind Lameness) and verify a very large divergence between the two representations, for example, the Left Hind Lameness chart with columns much larger than the Right Hind Lameness columns, or vice versa. If the representation in both representations columns that are not very significant and in a very similar way, there is a high possibility that there is no anomaly.

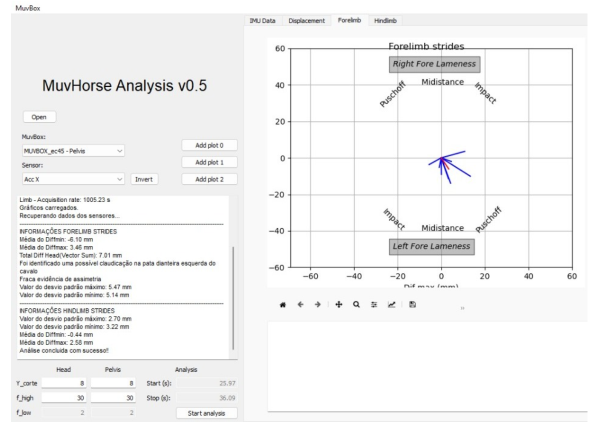

Fig. 5: Image of the Forelimb Strides chart in the program interface, with the information for the user in the region on the left.

Fig. 6: Image of the Hindlimb Strides chart in the program interface, with the information for the user in the region on the left.

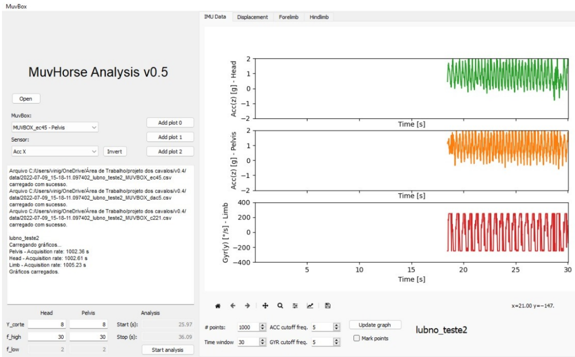

Fig. 7: Program interface with information on acceleration as a function of time for the head and pelvis, as well as the paw gyroscopic.

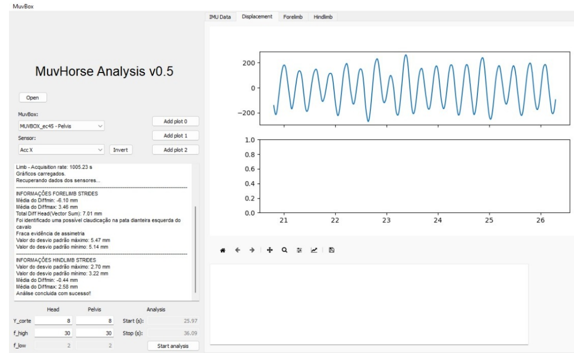

Fig. 8: Representation of displacement as a function of time in the program interface

A. Program interface and user information

The Forelimb Strides and Hindlimb Strides graphs are the main graphical information that appeared to the user, however, they are not the only information that appears.

Regarding the information correlated to Forelimb Strides, in addition to the graph, the average values of the Min and Max Diffs, the value of the maximum and minimum standard deviation and a message notifying which of the limb a possible lameness was identified is presented. The value of the Vector Sum (Total Diff Head) will also be informed, which is the value of the vector module in red of the graph. This information is found on the left side of the application interface, as shown in Fig.5.

Concerning the Hindlimb Strides graph, the information that appears includes the values of the maximum and minimum standard deviation and the values of Diffmin and Diffmax. This information is found on the left side of the application interface (see Fig.6).

In Fig.7 we have a representation of the result that appears to the user after selecting the data for analysis. The first graph is the representation of the head acceleration data, followed by the pelvis acceleration, and finally the gyroscope data.

In Fig.8 we have a plot of displacement versus time after integration in the frequency domain. In Fig.5 and Fig.6 we have the representation of the Forelimb and Hindlimb graphs and in the window on the left side of the program interface the written information that is provided to the user.

V. CONCLUSION

The detection of lameness in horses is a very rich field to be explored, dealing with an existing problem that afflicts many sectors that work directly with these animals. We propose a system to assist the identification of lameness and, essentially, identify which is the injured limb. The developed application presents a simple and very intuitive interface for the end user, regarding the execution and system implementation. However, it is understood that the project is still in early stages and there are many points to be improved and many tests in horses for the validation of the lameness identification.

REFERENCES

[1] J. B. Kaneene, W. A. Ross, and R. Miller, "The michigan equine monitoring system. ii. frequencies and impact of selected health problems," *Preventive Veterinary Medicine*, vol. 29, p. 292, 1997.

[2] "National economic cost of equine lameness, colic, and equine protozoal myeloencephalitis (epm) in the united states," *United States Department of Agriculture*, pp. 1–4, 2001. [Online]. Available: http://www.aphis.usda.gov/vs/ceah/cahm

[3] F. M. S. Bragança, M. Rhodin, and P. R. van Weeren, "On the brink of daily clinical application of objective gait analysis: What evidence do we have so far from studies using an induced lameness model?" *Veterinary Journal*, vol. 234, pp. 11–23, 4 2018.

[4] S. Dyson, "Recognition of lameness: Man versus machine," *Veterinary Journal*, vol. 201, pp. 245–248, 9 2014.

[5] R. S. Parkes, R. Weller, A. M. Groth, S. May, and T. Pfau, "Evidence of the development of 'domain-restricted' expertise in the recognition of asymmetric motion characteristics of hindlimb lameness in the horse," *Equine Veterinary Journal*, vol. 41, pp. 112–117, 2 2009.

[6] K. G. Keegan, E. V. Dent, D. A. Wilson, J. Janicek, J. Kramer, A. Lacarrubba, D. M. Walsh, M. W. Cassells, T. M. Esther, P. Schiltz, K. E. Frees, C. L. Wilhite, J. M. Clark, C. C. Pollitt, R. Shaw, and T. Norris, "Repeatability of subjective evaluation of lameness in horses," *Equine Veterinary Journal*, vol. 42, pp. 92–97, 3 2010.

[7] M. Hewetson, T. M. Christley, I. D. Hunt, and L. C. Voute, "Investigations of the reliability of the observational gait analysis for the assessment of lameness in horses," *Veterinary Record*, vol. 158, pp. 852–858, 6 2006.

[8] C. J. Fuller, B. M. Bladon, A. J. Driver, and A. R. Barr, "The intra- and inter-assessor reliability of measurement of functional outcome by lameness scoring in horses," *Veterinary Journal*, vol. 171, pp. 281–286, 3 2006.

[9] A. M. Hardeman, F. M. S. Bragança, J. H. Swagemakers, P. R. van Weeren, and L. Roepstorff, "Variation in gait parameters used for objective lameness assessment in sound horses at the trot on the straight line and the lunge," *Equine Veterinary Journal*, vol. 51, pp. 831–839, 11 2019.

[10] T. Pfau, T. H. Witte, and A. M. Wilson, "A method for deriving displacement data during cyclical movement using an inertial sensor," *Journal of Experimental Biology*, vol. 208, pp. 2503–2514, 7 2005.

[11] "Muv technology," urlhttp://https://muvtecnologia.com.br/, 2022.

[12] V. B. Guimarães and A. Girardi, "Frequency domain method for drift-free displacement estimation from acceleration data," *37º Simpósio Sul de Microeletrônica, 2022, São Leopoldo. SIM*, pp. 1–4, 2022.