Internet of the Equine - IIB Project Summary

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1 Introduction

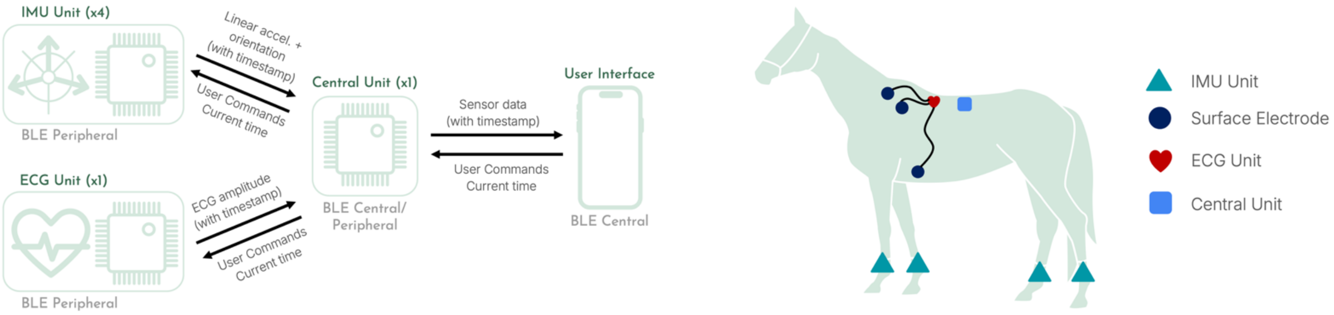
Horseracing is a controversial sport: while it has historical, cultural and economic significance in many communities, it often draws criticism from animal rights activists due to racehorse mistreatment and injury. Reaching top speeds of 70 km/h on race days [1], racehorses can suffer from overexertion and collapse. In 2023, the British Horseracing Authority found a 0.18% incidence rate [2] of sudden racehorse death (SD). Although this SD rate is a fraction of a percent, it is much higher than the equivalent statistic for human athletes (1.49 per 100000) and represents a tragedy every time it happens. [3] Sudden death most often has a musculoskeletal or cardiorespiratory cause. When the latter is at fault, SD could be predicted via measurement of heart rate or heart rate variability (HRV). Hence, there is scope for creation of a monitoring device to flag unwell horses before collapse occurs.

2 Aims and Objectives

The aim of this project was to produce a wearable system which collects both ECG and gait data, transmitting this information to a smartphone in real time. To this end, it was required to:

1. design and manufacture a functioning prototype;
2. test the system on a horse and;
3. analyse the obtained data to develop appropriate heart rate detection and stride rate estimation algorithms.

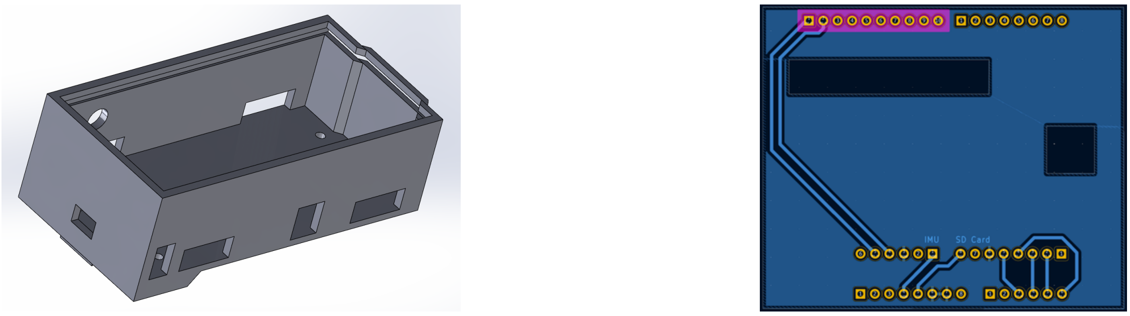
3 Design



(a) (b)

Figure 1 - System overview in terms of (a) data transmission and (b) sensor placement

As illustrated by Figure 1(a), the full system contains four IMU units and one ECG unit, coordinated by a central unit. To minimise use of wired connections, which could prove hazardous for a galloping horse, all devices communicate via Bluetooth Low Energy (BLE). A user device (for example, a mobile phone) connects to the central unit, sending instructions to begin or stop measurements, as well as adjust sampling parameters. In turn, the central unit relays these commands to the sensing units. During measurement, data is sent first to the central unit, which collates transmissions from all the sensing units and forwards them to the user as a group. Figure 1(b) shows the placement of the units on the horse, with one IMU unit on each leg, the ECG and central units placed on the roller, and electrodes in the equine exercise configuration.



(a) (b)

Figure 2 - Design of (a) mechanical case and (b) IMU PCB

(a) (b) (c)

Figure 3 - Fully assembled devices. (a) IMU unit, (b) ECG unit and (c) unit with lid

The devices used nRF52840 DKs as microcontrollers. Figure 2(a) shows a 3D model of the device case, which contains mounting holes in the base to secure the DK, as well as various slots to expose the USB port, on/off switch, plug in the ECG leads and thread Velcro straps through. The case was 3D-printed in Tough PLA, chosen for its advantageous mechanical properties. The lid was made of laser-cut plywood. This is slid into the case via the slot at the end and bolted in place.

Acceleration and orientation data were measured by the BNO055, an IMU with an inbuilt fusion algorithm. Due to the small amplitude and high noise expected in the ECG trace, a specialised signal conditioning block (AD8232) was added to the ECG units. All sensor units also contained an SD card so that a local copy of measurement data could be stored. To connect these electronic components to the DK, PCBs were designed and manufactured (Figure 3(b)). The fully assembled devices are shown in Figure 3.

4 Testing

(a) (b) (c)

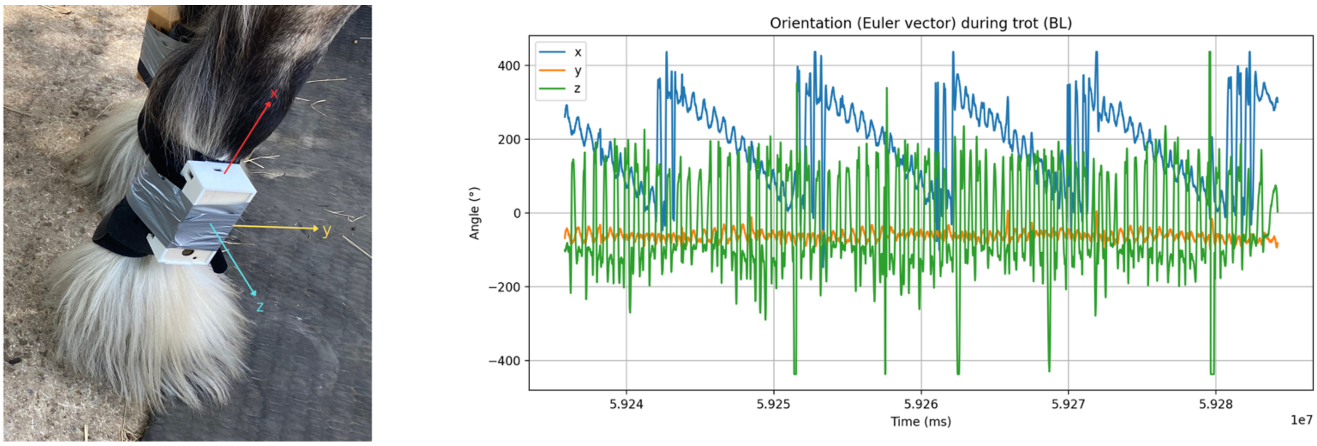
Figure 4 - Positioning of (a) units, (b) ECG electrodes and (c) electrode-securing bandage

(a) (b)

Figure 5 - Movement tests, including (a) walk, (b) trot and canter.

Figure 4 shows system placement on an actual horse. For extra security, the IMU units have been taped to the legs, while the electrodes are covered with a bandage. Measurements were taken while the horse was stationary, walking around the testing area and moving at higher speeds (trot and canter) in a circle around the handler.

5 Results



(a) (b)

Figure 6 - Orientation (a) axes and (b) time domain plot

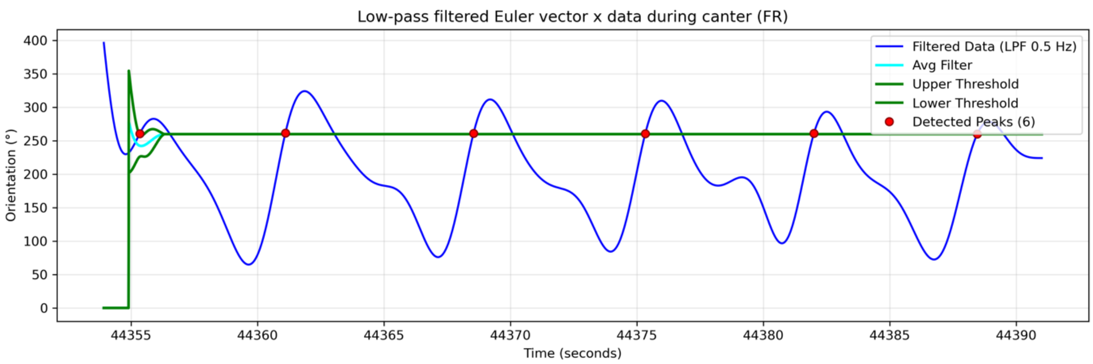
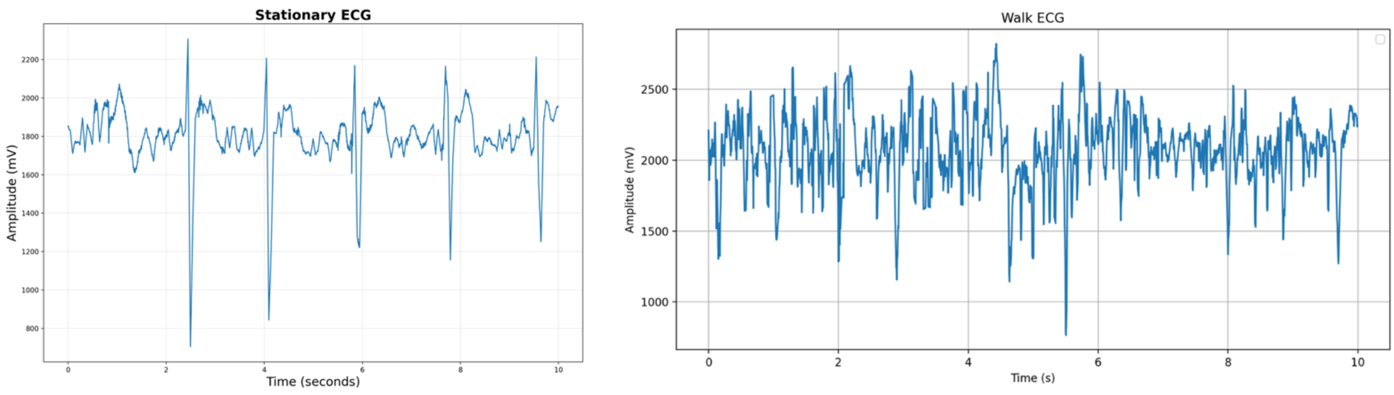


Figure 7 - Application of peak detection algorithm for lap rate estimation in canter

There was clear periodicity in the orientation data (given as rotation about the axes defined in Figure 6(a)). In particular, the low-frequency component in x-orientation corresponded to lap frequency, whereas the high-frequency component in both x- and z-orientation corresponded to stride frequency. As illustrated by Figure 7, a Z-score based peak detection algorithm was applied, achieving less than 12% and 3% error in the median stride and lap rate respectively.



(a) (b)

Figure 8 - ECG traces for (a) stationary and (b) walking horse

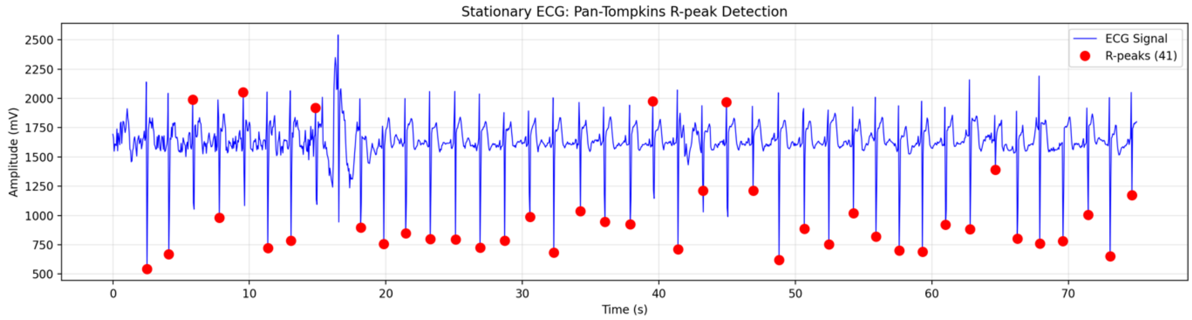


Figure 9 - Application of Pan-Tompkins detection to stationary ECG

Figure 8 illustrates a key issue with the ECG data: while the trace taken from a stationary horse (Figure 8(a)) had clear QRS complexes, even gentle movement degraded signal quality significantly (Figure 8(b)). Several common peak-detection algorithms were tested on the data, including Pan-Tompkins, the Hilbert-Huang Transform and the Wavelet Transform. Of these three, Pan-Tompkins was found to yield the best performance, as shown by Figure 9. However, due to the noisiness of the ambulatory ECGs, real-time estimated heart rate had significant peaks and troughs due to missed or double-counted peaks. While there was still less than 5% error in median heart rate (evaluated against a value produced by the FFT), the local fluctuation in estimated values hindered HRV analysis.

6 Conclusion

In the field, the system functioned well, with inter-unit and central-user connection maintained at all times. While stride and lap rate estimation were successful, as well as heart rate estimation to a lesser extent, HRV analysis could not be performed on the collected data. Future work to resolve this issue could involve experimentation with higher sampling rates and different electrode design.

7 Bibliography

[1] Q. Mercier and A. Aftalion, "Optimal speed in thoroughbred horse racing," *PLoS One,* vol. 15, pp. 1-18, 2020.

[2] P. Scargill, "Marginal drop in equine fatality rates recorded in British racing last year," *Racing Post,* 7 February 2024.

[3] M. Dennis, A. Elder, C. Semsarian, J. Orchard, I. Brouwer and R. Puranik, "A 10-year review of sudden death during sporting activities," *Heart Rhythm,* vol. 15, no. 10, pp. 1477-1483, 2018.