Recurrence plot quantification analysis of greyhound galloping gait

Hasti Hayati, David Eager and Sebastian Oberst
School of Mechanical and Mechatronic Engineering, Faculty of Engineering and Information Technology, University of Technology Sydney, Sydney, NSW, Australia

Abstract. Greyhounds are the fastest and most agile breed of canine and can reach a galloping speed of 70 km/h. Due to their high galloping speed they have been used for sprint racing for centuries. When the racing greyhound is running at its limit state injuries occur. To understand the underlying mechanisms of racing injuries, the galloping gait dynamics need to be understood. In this research a single inertial measurement unit equipped with a tri-axial accelerometer is used to measure the galloping dynamics of greyhounds. This research investigates greyhound galloping using nonlinear-time-series analysis measuring specifically recurrence plot quantification analysis.

Introduction

In this research, the possibility of using a single inertial measurement unit (IMU) to explain greyhound galloping characteristics is explored. This method was chosen as it is capable of reliably providing data in-situ on the greyhound during a race. The IMU was mounted approximately over animal's wither in a racing jacket with a pocket to accommodate the sensor. The time-domain signals, which were synchronised with high-frame videos, revealed that an instantaneous force up to fifteen times the greyhound's body weight is acting on hind-legs. Also, the time-domain signals for turning during galloping were different from those during straight galloping [1,2]. The frequency-domain data obtained by applying a fast Fourier transform (FFT) showed a dominant frequency at around 3.5 Hz which matches the greyhound galloping stride frequency.

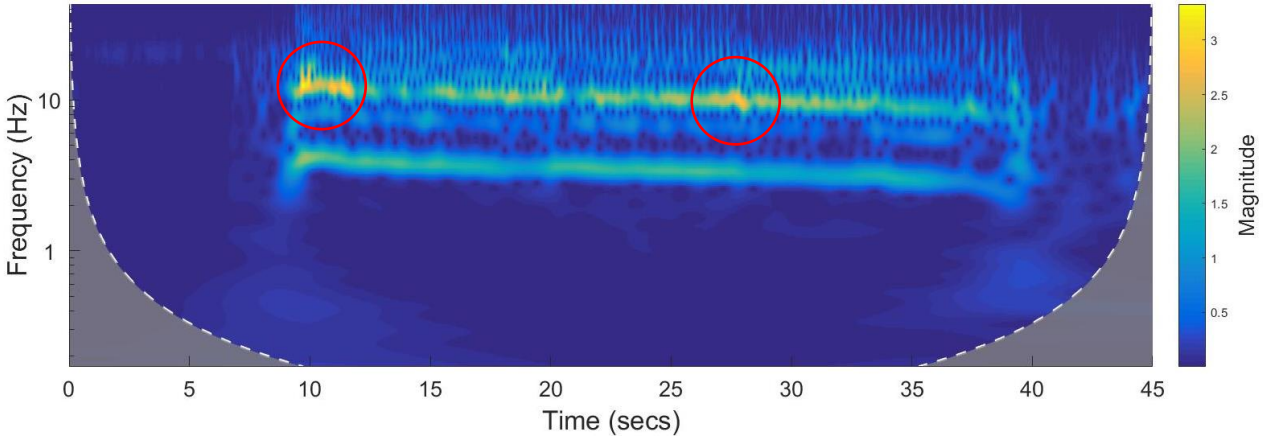

Figure 1: Morlet wavelet power spectrum of anterior-posterior acceleration of a typical greyhound racing track. Abrupt changes in the spectrum are highlighted by red circles.

Results and Discussion

The discrete wavelet transform was applied on data which highlighted fatigue during racing, indicated as abrupt signal alterations depicted in Figure 1, where the time-varying frequency (Hz) is plotted against time (s). Magnitude (indicated by colour gradient) refers to the value of the anterior-posterior acceleration. Abrupt changes in signals suggest anomaly in the gait, which may be caused by the design of the track, such as the lack of a transition into and out of the bend [1].

Although the linear-time-series analysis (FFT and Morlet wavelet power spectrum) could provide informative data with regards greyhound gait, they are limited and are not the best tools to understand complex and highly nonlinear dynamics or transient processes of galloping greyhounds. Thus, frequency and wavelet analysis are compared to each other and complemented by a recurrence quantification analysis based on embedding the dynamics in the phase space which is suitable to study nonlinear dynamics but also allows a study of stochastic processes and non-stationary events. It is shown that more information can be extracted by using nonlinear-time-series analysis measures than frequency and wavelet domain analysis. The degree of nonlinearity and linearity in different stages of the race are explored and reveal that additional information content due to nonlinearity can be extracted at any time within the race, but more so when the dog is running in a curve. The potential of using the phase space to assist in extracting features of the galloping greyhound's dynamics is discussed.

References

[1] Hayati, H., Mahdavi, F., Eager, D. (2019) Analysis of agile canine gait characteristics using accelerometry. *Sensors* **19(20)**:4379.

[2] Hayati, H., Walker, P., Mahdavi, F., Stephenson, R., Brown, T., Eager, D. (2018) A comparative study of rapid quadrupedal sprinting and turning dynamics on different terrains and conditions: Racing greyhounds galloping dynamics. ASME International Mechanical Engineering Congress and Exposition, Proceedings (IMECE).