Cyclists' Cardiac Conundrum

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Introduction

Problem:

Evidence suggests that those engaging in endurance sports training have an elevated risk of Atrial Fibrillation (A-Fib). *Electrocardiogram (ECG)* can diagnose *A-Fib* accurately but is often unavailable. Athletes typically record heart rate data (*Fig.1*).

What is "gappiness"?

"*Gaps*" are defined as discontinuity in heart rate data. It is unclear if gaps are caused directly by A-Fib, but past research has found a correlation between the proportion of "gappy" activities and reports of heart rhythm problems.

Our goal:

To develop methods for quantifying the degree of the irregularity using readily available heart rate data.

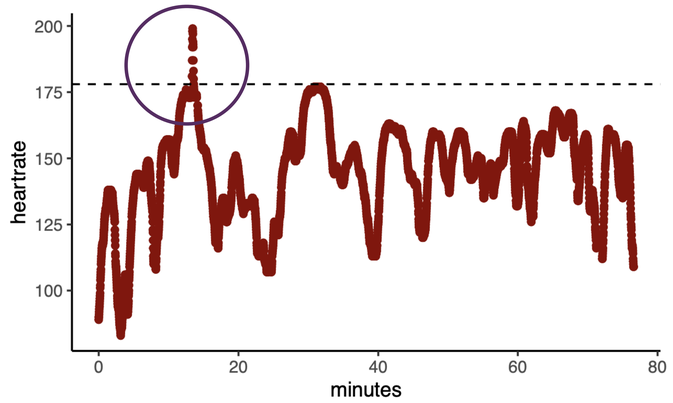


Figure 1: "Gappy" heart rate data in beats per minute (bpm)

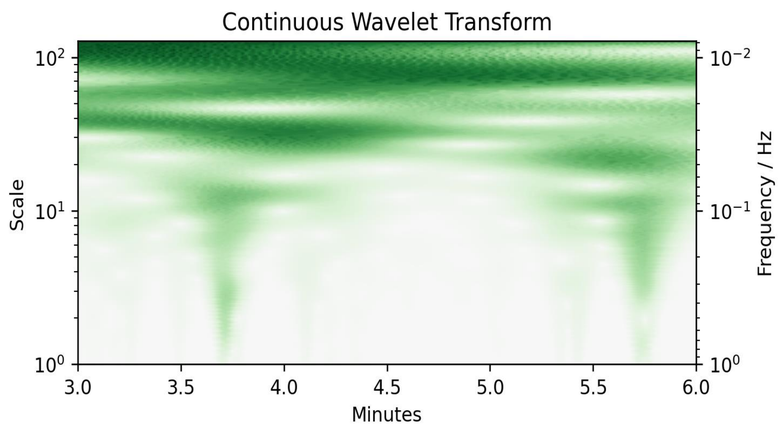


Figure 2: The CWT of the signal can be visualised as a heat map. Spikes extend into the small scales (high frequencies) at the bottom.

Simulation

Heart rate uses an SDE with asymmetric potential:

$$dX_t = -V'(X_t)\,dt + \sigma\,dB_t$$

Gap increments are added on according to an inhomogeneous Poisson process P_t.

$$dY_t = -\alpha Y_t + dP_t$$

These processes are added, smoothed and rounded to give the simulated heart rate.

Green, I and Dayer, M. Detecting arrhythmia from exercise data, 2021 (unpublished).

Daubechies, I. Ten lectures on wavelets, SIAM, 1992.

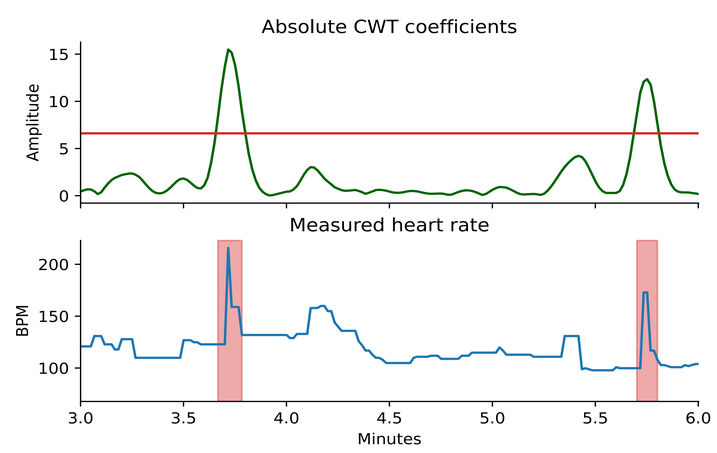


Figure 3: Using scale 3 (0.33Hz), spikes can be classified as regions when the modulus of the CWT exceeds a threshold.

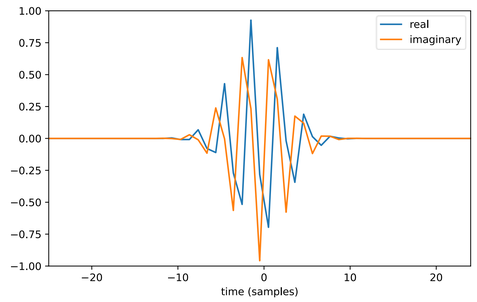
Spike detection

The continuous wavelet transform (CWT) breaks down a signal into localised frequency components.

$$(T^{WAV} f)(a,b) = \langle f, \psi^{a,b} \rangle = \frac{1}{\sqrt{|a|}} \int f(t) \bar{\psi}\left(\frac{t-b}{a}\right) \mathrm{dt}$$

$$\psi^{a,b}(t) = \frac{1}{\sqrt{|a|}} \psi\left(\frac{t-b}{a}\right)$$

Spikes in the signal appear in the higher frequencies (Fig.2). They can be detected by choosing a scale and thresholding the CWT (Fig.3).



The complex Morlet wavelet captures both amplitude and phase information.

The estimated rate of gaps can then be used as a measure of the irregularity.

What next?

1. Prepare and test gap detection algorithms on simulated data and apply on full data set.
2. Explore broader measures of heart rate volatility, such as stochastic volatility jump-diffusion models.
3. Investigate the suitability of machine learning pattern-recognition methods.