Real world signals: ECG from iAmp experiment

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May 22, 2018

Before attempting this section, you should have MATLAB data files corresponding to the RR interval (RRI) data from three trials – unconstrained breathing, constrained breathing at 50 beats per minute and constrained breathing at 15 beats per minute. (*Further details on splitting a single ECG recording into three segments and converting them to RRI data are given in your experiment handouts*)

Heart rate probability density estimate (PDE).
Using the RRI signal $rr[n]$ from Trial 1 (unconstrained breathing), obtain the heart rate $h[n]$ from

$$h[n] = \frac{60}{rr[n]} \tag{1}$$

To obtain a smoother estimate of the heart rate, use the following method to average every 10 samples of the heart rate:

$$\widehat{h}[1] = \frac{1}{10}\sum_{i=1}^{10} \alpha h[i], \;\; \widehat{h}[2] = \frac{1}{10}\sum_{i=11}^{20} \alpha h[i], \;\; \ldots \tag{2}$$

where α is a scalar.

a) Plot the probability density estimate (PDE) of the original heart rates $h[n]$ and the averaged heart rates $\widehat{h}[n]$ for $\alpha = 1$ and $\alpha = 0.6$. [5]

b) Comment on the shape of the PDE of the averaged heart rates compared to the original heart rates. How does the constant α affect the PDE? [5]

AR modelling of heart rate.

c) Find the autocorrelation sequence for the RRI data for the three trials. From the shape of the autocorrelation sequence, can you infer whether the RRI data is an AR or an MA process? (To ensure that your data is zero-mean, use the MATLAB command `detrend`). [5]

d) Using the tools and analyses for the AR modelling, argue whether the RRI signal for the three trials can be modelled by an AR(p) process. If so, what is the optimal AR model order? [5]

Respiratory Sinus Arrhythmia from RR-Intervals.
Respiratory sinus arrhythmia (RSA) refers to the modulation of cardiac function by respiratory effort. This can be readily observed by the speeding up of heart rate during inspiration ("breathing in") and the slowing down of heart rate during expiration ("breathing out"). The strength of RSA in an individual can be used to assess cardiovascular health. Breathing at regular rates will highlight the presence of RSA in the cardiac (ECG) data.

a) Apply the standard periodogram as well as the averaged periodogram with different window lengths (e.g. 50 s, 150 s) to obtain the power spectral density of the RRI data. Plot the PSDs of the RRI data obtained from the three trials separately. [10]

b) Explain the differences between the PSD estimates of the RRI data from the three trials? Can you identify the peaks in the spectrum corresponding to frequencies of respiration for the three experiments? [5]

c) Plot the AR spectrum estimate for the RRI signals for the three trials[1]. To find the optimal AR model order, experiment with your model order until you observe a peak in the spectrum (approximately) corresponding to the theoretical respiration rate. List the differences you observe between your estimated AR spectrum and the periodogram estimate in Part a). [10]

[1] Use the MATLAB function `aryule` to estimate the AR coefficients for your RRI signal.

References

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