

Signal Processing Methods For Heart Rate Variability Analysis

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Heart rate variability (HRV), the changes in the beat-to-beat heart rate calculated from the electrocardiogram (ECG), is a key indicator of an individual's cardiovascular condition. Assessment of HRV has been shown to aid clinical diagnosis and intervention strategies. However, the variety of HRV estimation methods and contradictory reports in this field indicate that there is a need for a more rigorous investigation of these methods as aids to clinical evaluation. This thesis investigates the development of appropriate HRV signal processing techniques in the context of pilot studies in two fields of potential application, sleep and head-up tilting (HUT).

A novel method for characterising normality in the ECG using both timing information and morphological characteristics is presented. A neural network, used to learn the beat-to-beat variations in ECG waveform morphology, is shown to provide a highly sensitive technique for identifying normal beats.

Fast Fourier Transform (FFT) based frequency-domain HRV techniques, which require re-sampling of the inherently unevenly sampled heart beat time-series (RR tachogram) to produce an evenly sampled time series, are then explored using a new method for producing an artificial RR tachogram. Re-sampling is shown to produce a significant error in the estimation of an (entirely specified) artificial RR tachogram. The Lomb periodogram, a method which requires no re-sampling and is applicable to the unevenly sampled nature of the signal is investigated. Experiments demonstrate that the Lomb periodogram is superior to the FFT for evaluating HRV measured by the $\frac{LF}{HF}$ -ratio, a ratio of the low to high frequency power in the RR tachogram within a specified band (0.04–0.4Hz). The effect of adding artificial ectopic beats in the RR tachogram is then considered and it is shown that ectopic beats significantly alter the spectrum and therefore must be removed or replaced. Replacing ectopic beats by phantom beats is compared to the case of ectopic-related RR interval removal for the FFT and Lomb methods for varying levels of ectopy. The Lomb periodogram is shown to provide a significantly better estimate of the $\frac{LF}{HF}$ -ratio under these conditions and is a robust method for measuring the $\frac{LF}{HF}$ -ratio in the presence of (a possibly unknown number of) ectopic beats or artefacts.

The Lomb periodogram and FFT-based techniques are applied to a database of sleep apnoeic and normal subjects. A new method of assessing HRV during sleep is proposed to minimise the confounding effects on HRV of changes due to changing mental activity. Estimation of $\frac{LF}{HF}$ -ratio using the Lomb technique is shown to separate these two patient groups more effectively than with FFT-based techniques. Results are also presented for the application of these methods to controlled (HUT) studies on subjects with syncope, an autonomic nervous system problem, which indicate that the techniques developed in this thesis may provide a method for differentiating between sub-classes of syncope.

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Contents

1	Introduction	1
1.1	Overview	1
1.2	Identifying the problem	2
1.3	Physiology of the human heart	2
1.3.1	ECG waveform generation and recording	4
1.3.2	Lead configurations	5
1.3.3	Heart disease	7
1.4	Abnormalities in the ECG - <i>ectopic</i> beats	7
1.5	The physiology of beat-to-beat heart rate control and HRV	8
1.5.1	The autonomic nervous system and the sympathovagal balance	9
1.5.2	Reflexes controlling heart rate and its variability	13
1.5.3	Factors influencing heart rate and its variability	14
1.5.4	HR and HRV correlation	19
1.6	Quantifying HRV	19
1.6.1	HRV metrics from the RR tachogram	19
1.6.2	Selected time domain measures of HRV	20
1.6.3	Scale-independent measures of HRV	21
1.6.4	Components in the frequency domain	24
1.7	The cardiovascular respiratory system - parameters and models	29
1.7.1	Baroreflex sensitivity	29
1.7.2	The connection between HR, HRV, BP and respiration - a possible mechanism	30
1.7.3	The DeBoer model	31
1.7.4	Data-driven models	34
1.8	The clinical utility of Heart Rate Variability	34
1.8.1	ATRAMI trials	35
1.8.2	Standardisation and clinical community recommendations	35
1.8.3	Standard terminology	36
1.8.4	Measurement standards	37
1.8.5	Physiological and pathophysiological correlates	38
1.8.6	Commercial manufacturers	39
1.8.7	Appropriate clinical applications	39
1.8.8	Future research areas	41
1.9	The problem of HRV measurement and repeatability	42
1.10	Overview of thesis	43
2	QRS detection	46
2.1	Introduction	46
2.2	QRS detection algorithms - overview	47
2.2.1	Available data — the MIT-BIH database	49

2.3	The Hamilton and Tompkins QRS detector	52
2.3.1	Detection of QRS complexes: Implementation of the Hamilton and Tompkins method.	54
2.3.2	Comparison of performance on MIT normal data	59
2.3.3	Discussion of results	61
2.4	Conclusion.	65
3	Abnormal Beat Detection in the ECG	66
3.1	Introduction	66
3.2	Pre-processing	67
3.2.1	Ectopic rejection	67
3.2.2	Artefact rejection	68
3.2.3	Robust methods	69
3.3	Using morphological information to identify normal QRS complexes	70
3.3.1	Template matching for the detection of ectopic beats	70
3.3.2	Neural Network for ECG analysis	75
3.3.3	The multi-layered perceptron	76
3.3.4	Auto-associative networks	78
3.3.5	Structure of auto-associative network for QRS reproduction.	79
3.3.6	Principal Component Analysis for architecture definition	82
3.3.7	Training the auto-associative network	82
3.3.8	QRS classification	86
3.3.9	Pruning the training set	90
3.3.10	Size of training set and training time.	90
3.3.11	VEB detection performance.	91
3.3.12	Initialisation with PCA	93
3.3.13	Conclusions	96
3.4	Using timing information to identify artefact and abnormal beats	97
3.4.1	Distribution of artefacts and ectopic beats	98
3.4.2	Data fusion algorithms	100
3.4.3	Summary	101
4	HRV experiments using spectral techniques	102
4.1	Overview	102
4.1.1	The RR tachogram - an unevenly sampled time series	102
4.1.2	FFT methods compared to AR methods	103
4.1.3	Re-sampling to enable spectral estimation	104
4.1.4	PSD estimation without re-sampling - the Lomb periodogram	105
4.2	From FFTs to the Lomb method - PSD estimation	105
4.2.1	The Discrete Fourier Transform	106
4.2.2	Generalising the DFT - PSD estimation via the Lomb periodogram	107
4.3	Practical considerations	111
4.3.1	Window size	111
4.3.2	Sampling frequency	112
4.3.3	Pre-processing	112
4.3.4	Performance metrics	112
4.4	Generating artificial data	113
4.4.1	A simple model	113
4.4.2	Spectral estimation of artificial RR time series	116

4.4.3	Frequency variation	117
4.4.4	Frequency resolution	119
4.5	Comparison of spectral estimation methods using artificial data	120
4.5.1	Comparison of even and uneven sampling for a single sinusoid	121
4.5.2	Comparison of even and uneven sampling for LF and HF components	124
4.5.3	Comparison of even and uneven sampling with frequency variation	128
4.6	Performance of algorithms on artificial data when coping with ectopy	130
4.6.1	Previous Work	131
4.6.2	Artificial ectopy	132
4.6.3	Beat replacement and removal: a comparison	134
4.6.4	Metric performance when removing or replacing ectopic beats	134
4.6.5	Discussion	135
4.7	Conclusions	136
5	HRV analysis during sleep	138
5.1	Introduction	138
5.2	Physiological control and variation	139
5.2.1	The autonomic nervous system	139
5.2.2	Circadian rhythms	140
5.3	Changes in HRV with activity	142
5.4	HRV and sleep	143
5.4.1	The physiology and classification of sleep	143
5.4.2	HRV changes with sleep state	145
5.4.3	Sleep disruption; pain, drugs and noise	147
5.5	Summary	147
5.6	Methods for analysing HRV during sleep	148
5.6.1	The MIT polysomnographic database	148
5.6.2	Preprocessing and artefact rejection	149
5.7	Mathematical analysis of HRV during sleep	151
5.7.1	Mathematical analysis	151
5.7.2	Results on normal subjects	153
5.7.3	Results on sleep apnoeic subjects	157
5.7.4	Comparison of PSD estimations methods for separating patients groups using REM and SWS	162
5.8	Conclusions	163
6	HRV: Applicability in controlled studies - Head-up tilts	166
6.1	Introduction	166
6.2	Syncope: Classification	167
6.2.1	Neurally mediated syncope	168
6.2.2	Orthostatic Hypotension	170
6.2.3	Cardiac arrhythmia/structural heart disease	170
6.2.4	Cerebrovascular (steal syndromes)	171
6.2.5	Controversial classifications	171
6.3	Syncope: Tests and Diagnosis	171
6.3.1	Head Upright Tilt Table Testing	171
6.4	HRV in the context of HUT and syncope	172
6.5	HUT data analysis	174
6.5.1	Methodology	174

6.5.2	Clinical protocol	174
6.5.3	Description of patients	175
6.5.4	Signal Analysis	182
6.6	Conclusions	184
7	Summary, conclusions and future work	185
7.1	Summary and key conclusions	185
7.2	Future work	187
7.2.1	Signal processing	187
7.2.2	Clinical studies	188
A	The MIT-BIH database	190
A.1	Appendix: The Annotation Definitions	190
B	Mathematical derivations	192
B.1	Appendix: Derivation of error back-propagation	192
B.2	Appendix: Karhunen-Loève Transformation	194
C	Normal Values of Standard Measures of HRV	196
D	Cubic Spline Interpolation	197
E	A Simple Illustration of the Lomb Periodogram	199