Measurement 42 (2009) 805–814

Contents lists available at ScienceDirect

Measurement

journal homepage: www.elsevier.com/locate/measurement

HRV and BPV neural network model with wavelet based algorithm calibration

G. Postolache [a], L. Silva Carvalho [c], O. Postolache [b], P. Girão [b,*], I. Rocha [c]

[a] Escola Superior de Saúde, Universidade Atlântica, Antiga Fábrica da Pólvora de Barcarena 2730-036, Oeiras, Portugal
[b] Instituto de Telecomunicações, IST, Av. Rovisco Pais, 1, 1049-001 Lisboa, Portugal
[c] Instituto de Medicina Molecular, Unidade de Sistema Nervoso Autónomo, Faculdade de Medicina, Universidade de Lisboa, Av. Professor Egas Moniz - 1649-028 Lisboa, Portugal

ARTICLE INFO

Article history:
Received 20 December 2006
Received in revised form 30 December 2008
Accepted 5 January 2009
Available online 10 January 2009

Keywords:
Autonomic nervous system
Wavelet transform
Neural network model

ABSTRACT

The heart rate and blood pressure power spectrum, especially the power of the low frequency (LF) and high frequency (HF) components, have been widely used in the last decades for quantification of both autonomic function and respiratory activity. Discrete Wavelet Transform (DWT) is an important tool in this field. The paper presents a LF and HF fast estimator that uses artificial neural networks and Daubechies DWT processing techniques. Radial Basis Function and Multilayer Perceptron neural networks were designed and implemented for fast assessment of cardiovascular autonomic nervous system control. The training values to design the networks were obtained after heart rate and blood pressure wavelets processing. The designed neural structures assure a faster evaluation tool of the sympathetic and parasympathetic autonomic nervous system control of the cardiovascular function.

1. Introduction

Heart rate and arterial blood pressure are the fundamental physiological parameters for assessment of cardiovascular and hemodynamic functions in basic medical research as well as in clinical practice. During the last two decades, the spectral analysis of heart rate variability (HRV) and blood pressure variability (BPV) have been providing important insights into neuronal control of the heart and blood vessels functions and considerable diagnostic utility in assessing cardiovascular and respiratory autonomic nervous system function [1–7]. A number of studies have suggested that the measurement of variability has important prognostic cardiovascular implications [8,9]. Many studies refer to the Fast Fourier Transform as one of the important methods to obtain the low frequency (LF) and high frequency (HF) information [1,2] but time length constrains (not less than 5 min) and required stationarity make this method less attractive for short time intervals (5–30 s) associated to autonomic nervous system changes. Digital wavelet transforms proved to be a good solution [7,9–13] for time–frequency analysis of heart rate and blood pressure signals allowing time visualization of the contribution of the LF signal component (related with sympathetic outflow), of the HF signal component (related with parasympathetic outflow and respiratory rhythm) and of the LF/HF ratio as an indicator of the balance between sympathetic and parasympathetic outflows. Previous works of the authors in the autonomic nervous system assessment were related to the design and implementation of wavelet-based algorithms for the evaluation of heart rate variability and blood pressure variability on rats [10,13]. Several correlations between the results of wavelet analysis and real physiological evoked response to experimentally induced changes were underlined based on wavelet analysis. With this approach, relative contributions of the two branches of the autonomic nervous system

* Corresponding author. Tel.: +351 218417289; fax: +351 218417672.
E-mail addresses: gabrielap@uatla.pt (G. Postolache), octavian.postolache@ist.utl.pt (O. Postolache), psgirao@ist.utl.pt (P. Girão).

0263-2241/$ - see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.measurement.2009.01.003

(sympathetic and parasympathetic systems) are assessed. Likewise, information from short-time cardiovascular signal analysis can be inferred on autonomic nervous system outflow.

In this work special attention was granted to the design and implementation of an automatic system for the measurement of physiological parameters on rats that provides estimation of cardiovascular autonomic modulation based on intelligent algorithms. A study related to fast modeling methods of multivariable systems was carried out. In this way design aspects such as the selection of an optimal sampling frequency of the measured signal and the analog-to-digital converter's resolution were considered. Intelligent algorithms, such as artificial neural networks and fuzzy systems showed to be important candidates for fast estimation of systems' internal parameters [14,15] particularly for autonomic nervous system control of the cardiovascular function. Different solutions based on neural networks modeling are reported in the literature both for static and dynamic characteristics of different kind of systems including biological systems [16–18]. Artificial Neural Networks (ANN), with their remarkable ability to derive meaning from complicated or imprecise data, can be used to extract patterns and detect trends that are too complex to be noticed by either humans or other computer techniques. A trained neural network can be thought of as an "expert" in the category of information it has been given to analyze. Thus, considering ANN advantages such as high degree of generalization and parallel computing [19], the present paper proposes a novel solution for fast evaluation of cardiovascular autonomic modulation based on neural networks using a DWT *calibration* algorithm.

2. LF and HF reference estimator based on wavelets

Time series were constructed from electocardiograms (Neurolog) and blood pressure signals from 20 male Wistar rats (400–460 g), anesthetized (α-chloralose, 100 mg/kg) with spontaneous respiration (10 rats) or artificially ventilated and paralysed (pancuronium bromide, 4 mg/kg/h) (10 rats). The femoral artery and vein were catheterised for pressure measurement (pressure transducer Sensonor 840 driven by a Lectromed Ltd. amplifier) and the admin-

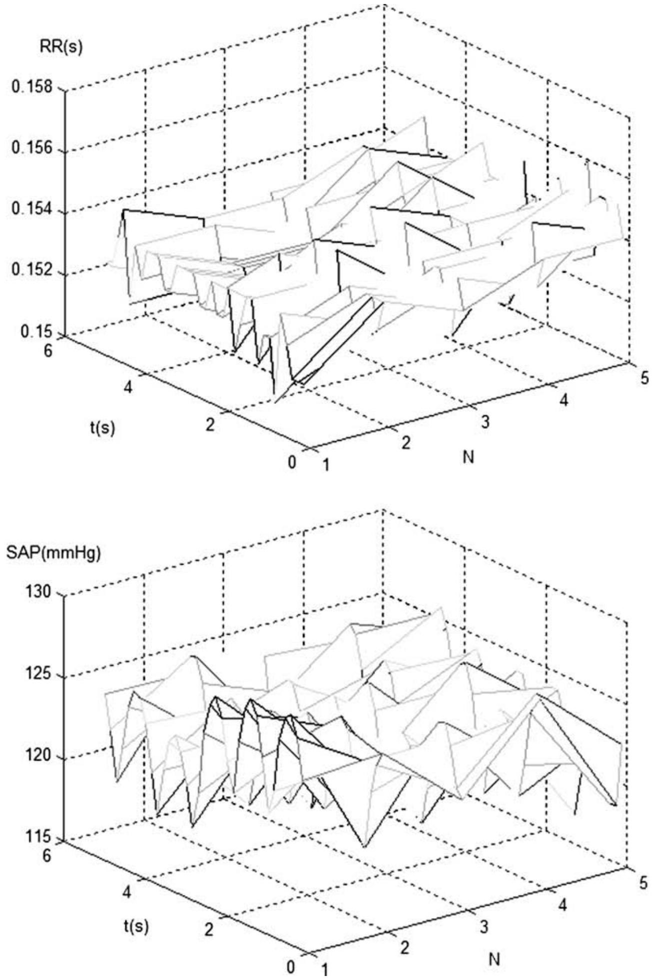

Fig. 1. RR interval and systolic arterial pressure (SAP) variability in rat with spontaneous respiration (N, number of signals; t, analysed time interval).