Computer Based Tool for Temporal and Spectral Analysis of Electrocardiographic Records

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Abstract

Along the last years the relationship between autonomic nervous system (ANS) function and cardiovascular mortality has been recognized as a fact. This has lead researchers to focus on quantitative indicators for autonomic balance, which are able to work as markers for several diseases, even at early states. At this point, Heart Rate Variability (HRV) has been reported to be one of the most promising methods for the diagnostic and study of Parkinson disease. In order to obtain quantitative indicators, several temporal and spectral parameters have been proposed. This work introduces a virtual bioinstrument specially designed for its use at neuro-vegetative studies for the diagnostic of Parkinson disease.

1. Introduction

Medicine in general and cardiology in particular have taken advantage of the advances on biomedical signal processing for the diagnostic and evaluation of the cardiovascular function. Some techniques developed under these contexts have jumped recently to other fields of medicine, such as happens with Heart Rate Variability (HRV) analysis, which is considered to be one of the most promising techniques for the evaluation of the evolution of Parkinson disease (PD) [1]. This technique enables the study of the relationship among the heart and the nervous system in a non invasive manner.

The self-regulation system of the heart, which generates rhythmic stimuli that triggers the contraction of the cardiac muscle, is modulated by sympathic and parasympathic fibres of the autonomous nervous system (ANS) coming from the cardiovascular centre located at brain stem.

On the one hand, sympathic stimulation appears to act by increasing the depolarization rate of the sinusal node, leading to tachycardia, and decreasing the HRV. On the other hand, parasympathic stimulation favours the liberation of acetylcholine, reducing the discharge rate of the sinusal node, leading to bradycardia and increasing the HRV [2].

Besides, this modulating process is governed by the Central Nervous System (CNS) within a closed loop control system (see figure 1). The CNS receives different stimuli as inputs and uses the ANS in order to send the proper answer to the heart. This answer alters the heart rate, as well as other cardiovascular variables, such as blood pressure, which is sensed through the baroreceptors, and feed-backed to the CNS. Since this control loop is running continuosly, the analysis of the HRV enables the study of the ANS in a noninvasive manner, through the use of well known techniques such as ECG analysis.

2. Methods

The standard steps for HRV determination are implemented in the proposed platform [3][4]. In this sense, the raw ECG time series is debugged in order to minimize the effect of artifacts. Once that a “clean” version is available, a QRS complex detecting algorithm is applied in order to obtain the inter-beat intervals. These lead to a new series, the tachogram, which will be transformed into the frequency domain in order to obtain the heart rate variability of the analyzed record.

Since the classical model of the R-R’ series as $1/f\alpha$ noise (Otsuka et al. 1995) requires of a large number of samples, holter records will be used (240 Hz sample rate @ 12 bits). Besides, since the desired spectral resolution is 0.005 Hz (over a 0.4Hz band), a minimum length of 10 minutes is required per each record.

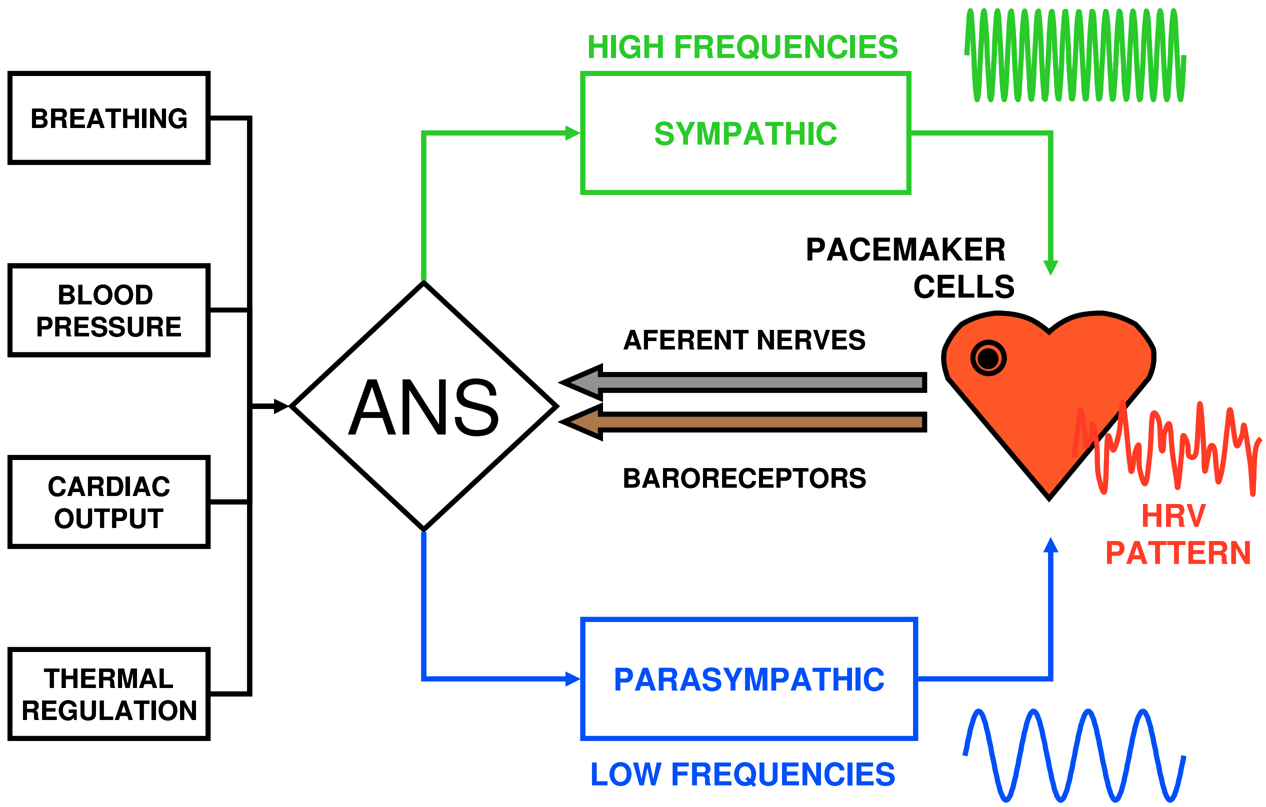

Figure 1. The closed-loop control system of the heart as modulated by the ANS

Supposing a standard 60 bpm heart rate, this leads to a minimum time series length of 600 beats. In order to minimize the influence of artifacts, the theoretical record length is increased to at least 30 minutes (1800 beats). Finally, as the test protocol followed for ANS-heart balance [2] requires of 4 different evaluations, the minimum record length per patient extends up to 120 minutes (7200 beats).

In order to enhance data access to this "long" records, holter data can be either loaded (ASCII, WAV or EDF) or acquired as required. In this last case, this can be done by means of a NIDAQ supported data acquisition board or through the computer's soundcard, sampling up to 44 KHz and then decimating the signal back to the original sample rate.

The preprocessing of the holter records is done be means of a built-in data editor, which includes baseline restoration, beat replacement among other classical methods, besides of a simple but yet effective digital filter bank for removing powerline interferences as well as EMG artifacts.

Once the ECG signal is considered valid for analysis, the semiautomatic QRS detector is initialized. Again, artifact detection and beat repairing routines are included.

The analysis of the ECG is done in both time and frequency domains. The temporal parameters considered are the average of the Inter-beat Interval (IBI or R-R' interval, in milliseconds), the standard deviation of the IBI (R-R'D), the number of beats exceeding an IBI difference greater than 50 ms (Ndif50), and the accumulated heart rate (in bpm) [5].

The spectral energies at different bands (VLF 0-0.05 Hz, LF 0.05-0.15 Hz, HF 0.15-0.4 Hz) are used to calculate the Sympathic Activity Index (SAI), defined as the ratio of the energy in the VLF and LF bands of the spectrum. For this purpose, an estimation of the Power Density Spectrum is calculated by means of the Fast Fourier Transform (FFT). At this point, the built-in editor has proved useful for avoiding the loss of beats that would have lead to time domain discontinuities. The definitions of the HRV parameters considered and calculated by the software follow the guidelines given in [6].

Finally, the graphical user interface has been conceived to maximize the system usability by the medical community (see Figure 2). In this sense, the number of controls has been reduced to the minimum for operation under everyday conditions.

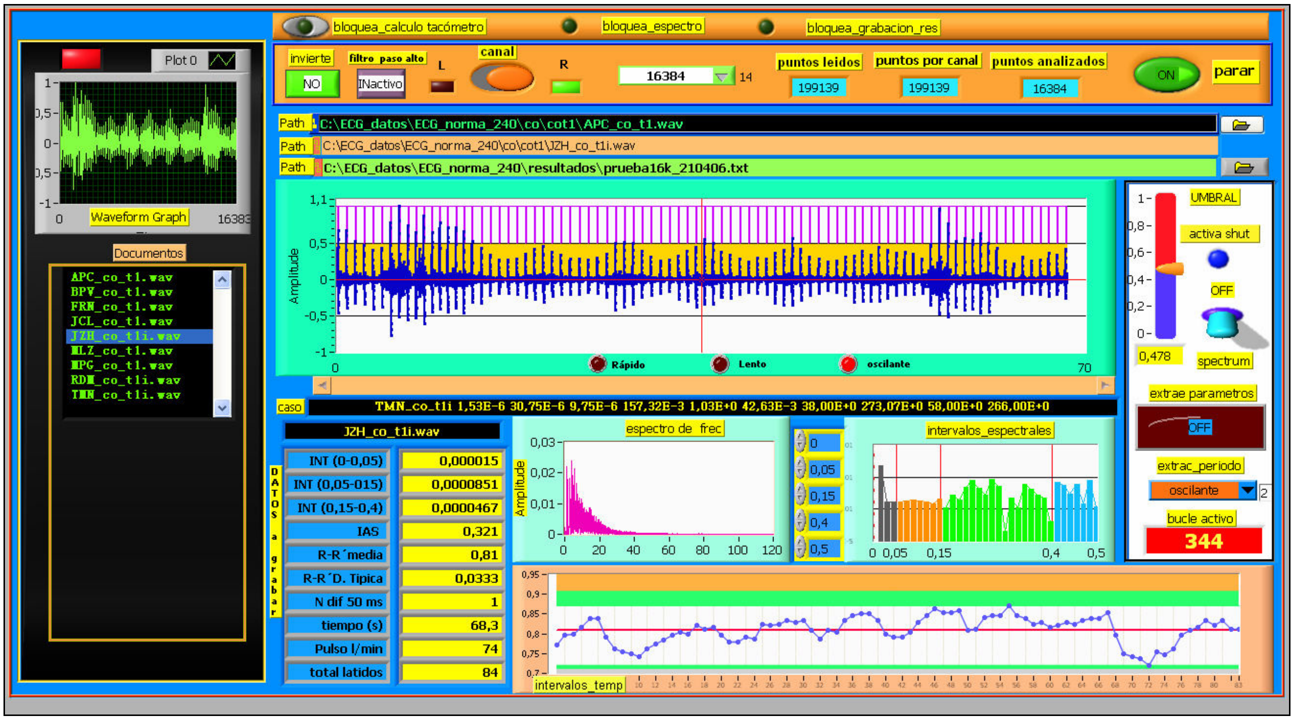

Figure 2. Graphical User Interface of the proposed software

3. Results

The presented software is currently being used within everyday examinations of Parkinson affected patients by the medical team, as this is the final goal of our research. The research stduy (approved by the ethics & research boards of the hospital) includes four patient groups (I: Non affected patients, II: Recently diagnosed PD patients with no prior PD treatment, III and IV PD patients under two different drug treatments). For each of the patients, the next trial protocol is followed: Deep Breathing Test, Valsava manoeuvre,, 30:15 Index, isometric exercise and blood pressure response to ortostatism. Finally, for the evaluation of this trials, the criteria of Ewing & Clark (1986) are followed. Starting from the result of these trials, the sensitivity of each of the indicators considered will be calculated in order to evaluate the manifestations on HRV of different degenerative parkinsonisms.

4. Discussion and conclusions

Programmed under LabView 7, the presented platform can be easily adapted to include additional algorithms. Currently, several non-linear processing algorithms are being integrated (finite growth rates, fractal dimension, entropy, etc.). The system is being currently used experimentally by the neurophysiology units of two hospitals (Santa Maria del Rosell in Cartagena and Hospital General de Alicante) for the screening of Parkinson through the evaluation of the autonomic balance.

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