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# Automatic identification of cardiac health using modeling techniques: A comparative study

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ABSTRACT

Heart rate variability (HRV), a widely adopted quantitative marker of the autonomic nervous system can be used as a predictor of risk of cardiovascular diseases. Moreover, decreased heart rate variability (HRV) has been associated with an increased risk of cardiovascular diseases. Hence in this work HRV signal is used as the base signal for predicting the risk of cardiovascular diseases. The present study concerns nine cardiac classes that include normal sinus rhythm (NSR), congestive heart failure (CHF), atrial fibrillation (AF), ventricular fibrillation (VF), preventricular contraction (PVC), left bundle branch block (LBBB), complete heart block (CHB), ischemic/dilated cardiomyopathy (ISCH) and sick sinus syndrome (SSS). A total of 352 cardiac subjects belonging to the nine classes were analyzed in the frequency domain. The fast Fourier transforms (FFT) and three other modeling techniques namely, autoregressive (AR) model, moving average (MA) model and the autoregressive moving average (ARMA) model are used to estimate the power spectral densities of the RR interval variability. The spectral parameters obtained from the spectral analysis of the HRV signals are used as the input parameters to the artificial neural network (ANN) for classification of the different cardiac classes. Our findings reveal that the ARMA modeling technique seems to give better resolution and would be more promising for clinical diagnosis.



## 1. Introduction

Heart rate variability, a measure of variations in the heart rate has been a subject of interest in biomedical and clinical research in the past years. It has been considered to be one of the most promising markers and has been extensively used to assess the autonomic tone [4]. Being a simple, non-invasive technique that provides an index of cardiac autonomic tone, observed HRV is believed to be an indicator of the dynamic interaction and balance between the sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS).

The interest in the analysis of heart rate variability (HRV), i.e., the fluctuations of the heart beating in time, is not new. The beat-to-beat variation in heart rate that reflects the time varying influence of the ANS and its components on the cardiac function has been used for investigating both cardiac and autonomic system function in both normal and diseased. With

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the advent of cheap and massive computational power, sophisticated methods have been developed in the application of signal processing techniques of heart rate analysis.

Past 20 years have witnessed the recognition of the significant relationship between autonomic nervous system and cardiovascular mortality including sudden death due to cardiac arrest [17,28,40]. Quantification of HRV using different measures led to the development of several commercial devices that aided both research and clinical studies which in turn provided automated measurements of HRV [20]. Several works cited in literature in connection to HRV-related cardiological issues [1–5,13,21,29,46] reiterated the significance of HRV in assessing the cardiac health.

Influenced by various physiological and pathological conditions, analysis of HRV has been widely used to assess the cardiac autonomic regulation. The most commonly used traditional approaches for HRV studies are (i) the time-domain analysis and (ii) the frequency domain analysis. Time-domain methods of HRV are simplest to use as they are based on common statistical measures. These methods are analyzed on the basis of calculations of the mean RR interval and the variations of the standard deviation of heart rate over time [4,11,46]. Changes in time-domain measures give an indication of the magnitude of change in autonomic tone. Some of the simple time-domain parameters include the SDNN (the standard deviation of all the normal–normal NN intervals) and the RMSSD (square root of the mean squared differences between adjacent NN intervals) [26]. Other time-domain measures are cited in a recent work by Sangthong et al. [42].

As regards to the frequency domain approach, spectral analysis is considered to be the most popular linear technique used in the analysis of HRV signals [8,38,50]. The spectral analysis of HRV is a well-established non-invasive way to investigate the autonomic control of the cardiovascular system [8,12,43]. Earlier studies have shown that the power spectrum was characterized by three main components [10,18,36]. The three bandwidths that are of importance in the power spectra of a HRV data are (i) high frequency (HF) band defined as 0.15–0.5 Hz, (ii) the low frequency (LF) band, defined as 0.04–0.15 Hz, and (iii) the very-low-frequency (VLF) band, defined as 0.0033–0.04 Hz. Despite the fact there is still a debate over the physiological interpretation of the spectral powers, it is widely believed that HF activity is associated with the heart rate modulation, the LF activity is associated with the intrinsic oscillations of the baroreceptor reflex and is mediated by both vagal and sympathetic systems and the VLF activity is associated the thermoregulation of vasomotor tone and with the rennin-angiotensin-aldosterone system.

Earlier works by researchers adopted the non-parametric method based on the fast Fourier transform algorithm(FFT) [10,19], while several others have used different parametric methods that included the techniques based on autoregressive (AR) models, moving averaging (MA) and autoregressive moving average (ARMA) models [34,36].

Methods based on Fast Fourier transformation and autoregressive analysis are most commonly used to transform signals into the frequency domain [24,35]. ECG signals were modeled using AR analysis for classifying cardiac arrhythmias. Results revealed that AR modeling was found to be useful for classification with reasonably high accuracies [19]. A very recent work by Oliver et al. [22] compared the performance of the epileptic and alcoholic EEG signals using FFT and AR modeling techniques using the peak amplitude and corresponding frequencies as the features. Power spectral density estimates of internal carotid arterial Doppler signals were obtained using both the classical fast Fourier transform and the model-based (AR, MA and ARMA) methods [47]. It was reported that a distinct qualitative improvement in the Doppler sonograms was obtained using the AR and ARMA methods over FFT and MA methods.

Even though the time-domain methods have been successfully applied in different clinical and research areas, it is the power spectral density that gives a deeper insight into the dynamics underlying the beat-to-beat RR variations. The main advantage of spectral analysis of signals over time-domain indices is the possibility to study frequency-specific oscillations (particularly in describing fluctuations in autonomic regulation in various physiological situations). Due to the gaining importance of the frequency domain methods in both research and clinical fields, we confined ourselves to adopting the different frequency domain techniques on the different cardiac classes that are included for our study.

In this work, we have studied the spectral analysis of nine types of cardiac classes using FFT, AR, MA and ARMA methods. The spectral parameters derived from these techniques were used as inputs to the Artificial Neural Network classifiers. The neural network was then used as a tool for the automatic classification of the normal sinus rhythm and the 8 different arrhythmias. This study was therefore designed to evaluate which among the frequency domain approaches would result in better resolution and henceforth could be used for clinical diagnosis.

This paper is organized as follows: The different cardiac classes for classification are explained and the preprocessing of the signals are discussed in Section 2. In Section 3, the spectral methods, both the classical and parametric approaches are discussed. This is followed by Section 4 that gives a description of the neural network classifier. Section 5 describes the statistics involved in this study. Section 6 gives the results of the spectral analysis of different cardiac classes which is followed by Section 7 where the classification results are discussed. Finally, the conclusions are drawn in Section 8.

## 2. Materials and methods

The data used for analysis in this work was obtained by recording ECG signals (of 10 to 15 minutes duration) of over 352 patients in lying condition. The permission from the clinicians and staff of the Kasturba Medical College Hospital, Manipal, India has been obtained to collect the data for this study. The original analog signal recorded in magnetic tapes (holter recording) was subsequently converted to digital equivalent by discrete time sampling and quantization. A sampling rate