Chapter 2

Artificial Neural Networks for Classification of Pathologies Based on Moments of Cardiac Cycle

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ABSTRACT

The advancement of cardiac pathology quantification hinges on the utilization of computer algorithms. To transform this vision into reality, these algorithms must distinguish among the most prevalent cardiac disorders. While some studies have leveraged the R-R interval for data extraction from ECG signals to diagnose various arrhythmias, this approach falls short in measuring changes in other ECG waves, like distortions in the P wave indicative of atrial fibrillation. This chapter introduces a new metric bi-level based on Shannon entropy to gauge the information within cardiac cycles, accounting for both the events themselves and their momentary decomposition. Experimental results reveal the method's high accuracy in classifying four distinct cardiac signal types (including one healthy signal and three pathological ones), achieving a classification rate ranging from 97.28% to 100% when employing a multilayer perceptron neural network. It holds great promise in aiding the diagnosis of cardiac pathologies.

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INTRODUCTION

It is well known that the heartbeat dynamics are modulated by the autonomous nervous system (Victor et al., 2003; Kuhtz-Buschbeck et al., 2020). In fact, most computational methods quantify the frequency modulation in heartbeats as a method to analyze the characteristics of the electrocardiogram (ECG) signal (Parvaneh et al., 2019), in a technique known as heart rate variability (HRV) (Zarei & Asl, 2020; Ebrahimzadeh et al., 2018; Sahoo et al., 2020).

HRV has been successfully used in many studies, obtaining high accuracy rates in helping the diagnosis of cardiac anomalies. Ebrahimzadeh et. al. (2018) classified Paroxysmal Atrial Fibrillation with accuracy of 98.21%. For this, they used a combination of linear and nonlinear features extracted from the HRV, being nine linear features, including five features of the time domain and four of the frequency domain, and eight nonlinear features. Jovic & Jovic (2017) developed a methodology for classifying arrhythmias that obtained accuracy of 91.20%. To do so, they used Alphabet Entropy and HRV applied to Random Forests. Kim et al. (2016) propose to classify patients with arrhythmia using 5-second windows for HRV as input data for the Support Vector Machine (SVM) classifier and achieved accuracy of 89.13% with the MIT-BIH arrhythmia dataset. Martins et al. (2013) automatically classified five types of heartbeats using high-order statistics. The five types of ECG beats are: healthy, right branch block, left branch block, premature auricular contraction, and premature ventricular contraction, obtaining mean accuracy of 93.48%. Tsipouras et al. (2004) studied heart rate-based resources to detect arrhythmia. This method yielded sensitivity and specificity of 87.5% and 89.5%, respectively, using only features in the time domain. The combination of features in the time domain and frequency domain reached sensitivity and specificity of 90% and 93%, respectively. Despite the large number of applications, HRV-based algorithms require a series of steps and adjustment until they reach high rates of correctness in the arrhythmia classification, for example, several layers and/or activation functions in neural networks, several kernels for Support Vector Machines (SVM), numerous neighbors in k-Nearest Neighbor (k-NN) (Yao et al., 2020; Sing et al. 2018; Poddar et al. 2019; Homaeinezhad et al., 2012).

In this paper we go one level deeper in the analysis of the cardiac dynamics by quantifying the changing statistics across each trajectory in the cardiac cycle in phase space. A cardiac cycle is defined by the signal (the trajectory) between consecutive QRS complexes, which can be easily accomplished through time domain segmentation. Synchronizing the analysis per cardiac cycle is preferable over performing predefined length window-based analysis because ECG dynamics are quasi periodic, so timing information will be lost in the subsequent analysis.

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