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Classification of Cardiac Abnormalities Using Heart Rate Signals: A Comparative Study

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The electrocardiogram (ECG) is the most important biosignal used by cardiologists for diagnostic purposes. The ECG signal provides key information about the electrical activity of the heart. Continuous ECG monitoring permits observation of cardiac variations over an extended period of time, either at the bedside or when patients are ambulatory, providing more information to physicians. Thus, continuous monitoring increases the understanding of patients' circumstances and allows more reliable diagnosis of cardiac abnormalities. Detection of abnormal ECG signals is a critical step in administering aid to patients. Often, patients are hooked up to cardiac monitors in hospital continuously. This requires continuous monitoring by the physicians. Due to the large number of patients in intensive care units and the need for continuous observation of them, several methods for automated arrhythmia detection have been developed in the past few decades to simplify the monitoring task. These include Bayesian [1] and heuristic approaches [2], expert systems [3], Markov models [4], self-organizing map [5], and Artificial Neural Networks (ANNs) [6].

Ham *et al*, have classified the ECG signal into two classes normal and PVC using fuzzy adaptive resonance theory mapping (ARTMAP) neural network with more than 99% specificity and 97% sensitivity [7]. Recently, Ozbay *et al*, have used multi-layered perceptron (MLP) with backpropagation training algorithm, and a new fuzzy clustering NN architecture (FCNN) for early diagnosis of ten different types of cardiac arrhythmia [8]. Their test results suggest that a new proposed FCNN architecture can generalize better than ordinary MLP architecture and also learn better and faster.

A new fuzzy Kohonen network, which overcomes the shortcomings of the classical algorithm, is presented to classify three cardiac arrhythmia (atrial fibrillation, ventricular fibrillation, and ventricular tachycardia) [9]. The proposed algorithm has achieved high accuracy (more than 97%) and is computationally fast in detection. A three RR-interval sliding window is used to classify the cardiac arrhythmia into four categories of beats (normal, premature ventricular contractions, ventricular flutter/fibrillation and 2 degrees heart block) was proposed [10]. This method indicates high performance: 98% accuracy for arrhythmic beat classification and 94% accuracy for arrhythmic episode detection and classification.

A novel method for detecting ventricular premature contraction (VPC) from the holter system was proposed using wavelet transform (WT) and fuzzy neural network (FNN) [11]. The major advantage of this method is to reuse information that is used during QRS detection, a necessary step for most ECG classification algorithm, for VPC detection. The method classifies the VPC correctly, with an accuracy of 99.79%. ECG arrhythmia classification into five different classes using principal component analysis was proposed [12]. Hebbian neural networks are used for computing the principal components of an ECG signal. An average value for classification sensitivity and positive predictivity were found to be 98.1% and 94.7% respectively. A number of neural network architectures were designed and compared with their ability to classify six different heart conditions [13]. Among different architectures, a proposed multi-stage network named NET_BST showed the highest recognition rate of around 93%. Therefore, this network proved to be suitable in ECG signal diagnosis. Khadra *et al* [14] have classified life threatening cardiac arrhythmias using wavelet transforms. Later, Al-Fahoum *et al* [15], have combined wavelet transformation and radial basis neural networks for classifying cardiac arrhythmias.

Acharya *et al*, have explained all the different types of linear, frequency and non-linear techniques, available for the analysis of heart rate signals [16]. They have also have classified the cardiac abnormality into eight different classes using neural network and fuzzy equivalence relations with an accuracy of more than 80% [17]. A neuro-fuzzy classifier called Fuzzy-Gaussian Neural Network (FGNN) was used to recognize the ECG signals for Ischemic Heart Disease (IHD) diagnosis [18]. The proposed ECG processing cascade had two main stages: (a) feature extraction from the QRST zone of ECG signals using either the Principal Component Analysis (PCA) or the Discrete Cosine Transform (DCT); (b) pattern classification for IHD diagnosis using the FGNN. This method classifies the IHD with an accuracy of almost 100%.

Features are extracted from higher order statistics and the Hermite characterization of QRS complex of the registered electrocardiogram (ECG) waveform. These features are fed to support vector machine (SVM) for the reliable heart beat recognition [19]. The reliable recognition and adequate electrical shock therapy of life-threatening cardiac states depend on the electrocardiogram (ECG) descriptors which were used by the defibrillator-embedded automatic arrhythmia analysis algorithms using twelve parameters [20]. The accuracy for the noise contaminated non-shockable and shockable signals exceeded 93%. Kannathal *et al*, have used an adaptive neuro-fuzzy network to classify heart abnormalities in ten different cardiac states with an accuracy level of more than 94% using heart rate signals [21]. Two different classifiers, decision-tree algorithm based on inductive learning from a training set and a fuzzy rule-based classifier for the identification of premature ventricular