Classification of Heartbeats Using Morphological and Dynamic Features of ECG Signal

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Abstract— This paper focuses a new approach for heartbeat classification based on a combination of morphological and dynamic features of ECG signal. In this study, wavelet transform and independent component analysis (ICA) will be applied separately to each ECG signal to extract morphological features. In addition, RR interval information will be computed to provide dynamic features. These two different types of features will be concatenated and a classifier will be utilized for the classification of heartbeats into one of five classes. The work will be validated on the baseline MIT/BIH arrhythmia database. The purpose of the paper is to achieve higher accuracy over other state-of-the-art methods for heartbeat classification.

Key words: ECG signal, heartbeat classification, independent component analysis, RR features

I. INTRODUCTION

Each individual heartbeat in the cardiac cycle of the recorded ECG (Electrocardiogram) waveform shows the time evolution of the heart's electrical activity, which is made of distinct electrical depolarization– re polarization patterns of the heart. Any disorder of heart rate or rhythm, or change in the morphological pattern, is an indication of an arrhythmia, which could be detected by analysis of the recorded ECG waveform. Real time automated ECG analysis in clinical settings is very helpful to clinicians in detecting cardiac arrhythmias, which often arise as a consequence of a cardiac disease, and may be life-threatening and require immediate therapy. However, automated classification of ECG beats is a challenging problem. [1]

Computer-Assisted (ECG or EKG) interpretation has been an intense research focus for decades. Research advances in automatic ECG analysis have made positive contributions to the timely detection and better management of cardiac disorders in clinical situations. Cardiac arrhythmias refer to a large group of conditions in which there is abnormal activity or behavior in heart [2]. Some types of arrhythmia are life-threatening medical emergencies that can trigger cardiac arrest and sudden death, such as ventricular fibrillation and tachycardia. Detection of such arrhythmias has been well investigated [3]. There are certain abnormalities arise in arrhythmia. Some of them are as follow:

S. No.	Name of abnormality	Characteristic features
1	Atrial fibrillation	Absence of P wave
2	Dextrocardia	Inverted P-wave
3	Tachycardia	R–R interval<0.6 s
4	Bradycardia	R–R interval>1s
5	Hyperkalemia	Tall T-wave and absence of P-wave
6	Myocardial Ischaemia	Inverted T-wave
7	Hypercalcaemia	QRS interval<0.1 s
8	Sinoatrial block	Complete drop out of a cardiac cycle
9	Sudden cardiac Death	Irregular ECG
10	Ventricular Fibrillation	Highly oscillated ECG

Table 1: Various Abnormalities And Their Characteristic

An essential step toward detecting and classifying arrhythmias is the classification of heartbeats, given that heart rhythm category can be determined by the recognition of classes of consecutive heartbeats [1]. Beat-by-beat human-based examination can be very time-consuming and tedious to be practical in many scenarios. Besides, automatic ECG analysis is significant in long-term online monitoring of cardiac activity for timely detection of abnormal heart conditions, in which case the human monitoring and interpretation is unable to satisfy real-time diagnosis requirements. Therefore, automatic heartbeat classification of ECG signals can be instrumental in the diagnosis of cardiac arrhythmias [4], [5].

This can be achieved by developing a computer assisted classification of heartbeat using morphological and dynamic features of ECG Signal without any medical instruments. The proposed method is to consider already recorded ECG signal for classification and to develop classifier for the classification of heartbeats [6], [7].

Although there are many other methods for the classification of ECG signals. This paper focuses on new representation of heartbeats using a combination of improved morphological and dynamics features extracted from ECG signals.

The paper extends study in the following aspects:

- Extracting morphological features by applying wavelet transform and independent component analysis (ICA) separately to each ECG signal.
- Computing RR interval information to provide dynamic features.
- Designing of a classifier for classification.
- Validation by using comparison of the results with the existing classification methods.

II. METHODOLOGY

MIT-BIH arrhythmia database [8] was developed as Standard database for detection and classification of arrhythmia ECG signals. The ECG signals are first preprocessed to remove artifacts. Following the preprocessing, the ECG signals are subsequently divided into heartbeat segments, using provided R peak locations. Wavelet transform (WT) and independent component analysis (ICA) are separately applied to each heartbeat and corresponding coefficients are concatenated and represented in a lower dimensional space using principal component analysis (PCA).

The resulting principal components that account for most of the variance are selected, which are utilized to obtain a morphological descriptor of the heartbeat. In addition, a set of RR interval features are derived to obtain a characterization of the dynamics information around the particular heartbeat. Following the feature extraction, a classifier is used for classifying heartbeats into 5 different classes.

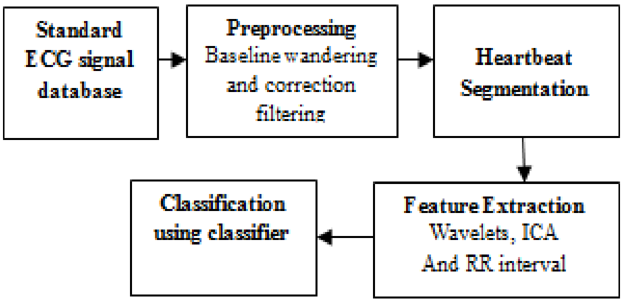

Fig. 1: Overview of the proposed automatic heartbeat classification methodology

A. ECG Signal Preprocessing

The preprocessing of ECG signals is necessary to reduce various types of noise that can be present in ECG signals, in order to improve the signal-to-noise ratio (SNR), which can be beneficial to the subsequent fiducial point (e.g., the location of QRS complex) detection and heartbeat classification. Following the signal is band-pass filtered at 5–12 Hz to maximize the energy of QRS complex, removing high-frequency and low- frequency artifacts. The filtered signals are used in subsequent processing.

B. Heartbeat Segmentation

One heart cycle of ECG signal typically consists of three basic waveform components, namely, P wave, QRS complex, and T wave. The provided annotations of R-peak locations from the database were utilized to obtain heartbeat segments.

C. Wavelet Transform

Wavelet Transform is used as a feature extraction method gives wavelet features. Daubechies wavelet of order 8 is to be selected due to their similarity with most characteristic QRS waveform. It can give the sampling frequency of 360 Hz, the highest possible frequency can be presented is 180 Hz. Applying the four level wavelet decomposition gives approximation and detail coefficients.

D. Independent Component Analysis

The goal of Independent Component Analysis (ICA) is to recover independent source signals from a set of observed signals, give little prior information and morphological features. ICA data has to be utilized in ECG signal analysis for blind source separation and feature extraction.

E. Principal Component Analysis

Morphological and dynamic features will be first concatenated and PCA will be applied to reduce the feature dimensionality. The tenfold cross validation will have to be performed on the lead A signals of the selected training dataset, in order to select dimensionality of the final morphological features, as depicted.

F. RR Interval Features

Besides morphological features, RR interval features are to be computed for characterizing the dynamic information of the heartbeat, termed as "dynamic" features. Four RR features are to be derived to represent the rhythm of the heartbeat at various scales, namely, previous RR, post RR, local RR, and average RR interval features.

G. Classifier

Classifier SVM (Support Vector Machine) is used for classifying heartbeats into one of the five AAMI heartbeat classes. SVM consists of building a hyper plane that maximizes the separation margin between two different classes. There are original 16 heartbeat classes are standardized by MIT-BIH arrhythmia database. These classes are re-clustered into the five bigger classes. The Association for the Advancement of Medical Instrumentation (AAMI) provides standards and recommended practices for reporting performance results of automated arrhythmia detection algorithms. These five-class scheme recommended by ANSI standard, namely N, S, V, F and Q are as shown in table II [9].

S. No.	AAMI classes	MIT-BIH classes
1	N (Any heartbeat not in S, V, F, or Q classes)	NOR,LBBB,RBBB,AE,NE
2	S (Supra Ventricular Ectopic Beat)	APC,AP,BAP,NP
3	V (Ventricular Ectopic Beat)	PVC,VE,VF
4	F (Fusion Beat)	VFN
5	Q (Unknown Beat)	FPN,UN

Table 2: Mapping From Mit-Bih Arrhythmias Heartbeat Classes to Aami Heartbeat Classes

III. Conclusion

This paper has presented the method which will process ECG signal for the classification of heartbeats, which is nothing but classification of cardiac arrhythmias. This method aims to extract important features both from the morphological and dynamic characteristics of the ECG signal and to develop ECG signal classifier by employing the extracted features.

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