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Feature extraction for ECG heartbeats using higher order statistics of WPD coefficients

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ABSTRACT

This paper describes feature extraction methods using higher order statistics (HOS) of wavelet packet decomposition (WPD) coefficients for the purpose of automatic heartbeat recognition. The method consists of three stages. First, the wavelet package coefficients (WPC) are calculated for each different type of ECG beat. Then, higher order statistics of WPC are derived. Finally, the obtained feature set is used as input to a classifier, which is based on *k*-NN algorithm. The MIT-BIH arrhythmia database is used to obtain the ECG records used in this study. All heartbeats in the arrhythmia database are grouped into five main heartbeat classes. The classification accuracy of the proposed system is measured by average sensitivity of 90%, average selectivity of 92% and average specificity of 98%. The results show that HOS of WPC as features are highly discriminative for the classification of different arrhythmic ECG beats.

1. Introduction

The automatic recognition of the arrhythmias from an electrocardiographic (ECG) record has been a very important subject. This is due to the fact that the accurate recognition and classification of various types of arrhythmias are essential for the correct treatment of the patient. Various algorithms for the automatic detection of ECG beats have been developed by different investigators for this purpose [1–33]. These researchers used various features and classification methods. A major obstacle in these studies is the fact that the symptoms of the diseases are not present all the time in the ECG records. So, a successful diagnosis might require examination of several hours of ECG record. The process is tedious and time consuming for experts and possibility of missing vital information is high. Therefore, computer-based automatic arrhythmia detection and classification systems are important in clinical applications. Although there has been a tremendous amount of improvement in technology and various approaches to the problem, automatic ECG beat detection and classification with high reliability is still an open research area.

In the literature, many researchers have addressed the problem of automatic detection and classification of cardiac rhythms [1–30]. In most of the studies, MIT-BIH ECG database is used. Some techniques are based on the detection of a single arrhythmia type and its discrimination from normal sinus rhythm, or the discrimination between two different types of arrhythmia [1–4]. Other classes of proposed methods for arrhythmia detection and classification are based on the detection of different heart rhythms and their classifica-

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tion into two or three arrhythmia types and the normal sinus rhythm [5–9]. Another field of interest is the ECG beat-by-beat classification, where each beat is classified into one of several rhythm types [10–14]. Methods beat-by-beat classification can classify more arrhythmia types.

In all these studies, the researchers used a variety of features to represent the ECG signal and a number of classification methods. The features has been based on higher order statistics [11,15–18,46], wavelet transform [19–24], Fourier transform [6,20,25], principle component analysis [26], Helmit function coefficients [17,27], morphological features such as RR-interval, QRS complex, QRS duration in time, T wave duration in time, P wave flag, and T-wave segment [6,11,12,18,21,28,29]. Moreover, different classifiers based on different systems such ANNs [6,11,16,19–22,25,26,30], mixture of experts approach [12], fuzzy logic [11,19], support vector machine [18–20,31], k-nearest neighbor [32,33], and SOM [27,30], are used.

There are varieties of reported performances of automatic arrhythmia classification systems in the literature. As mentioned above, the methods used and the number of arrhythmia types that are classified show a great deal of variance which makes it very difficult to fairly compare the performances of different algorithms. To overcome this difficulty, some standards are recommended for reporting performance results by the "Association for the Advancement of Medical Instrumentation" (AAMI) [28]. According to AAMI standards, all ECG beats in MIT-BIH database are grouped into five beat classes.

In this paper, wavelet packet decomposition (WPD) method which is an extension of wavelet transform has been used to analyze ECG beats. WPD is capable of dividing the whole time-frequency plane while classical WT can provide analysis only for low band frequencies. The multi-resolution capability of WT allows the decomposition of a signal into a number of scales, each scale representing a particular feature of the signal under study [34,35]. After WPD coefficients are obtained, HOS features (second, third, and fourth cumulants) are extracted for each subband of WPD. The HOS features of WPD coefficients are used as inputs to the classifier. k-NN type classifier is used since it does not require training and provides robust performance.

In the following section, the ECG data acquisition, preprocessing, and feature extraction steps are explained. In Section 2.6, descriptions of the classifier are given. The results are presented in Section 3. Finally, the conclusions are derived based on the results of the study in Section 4.

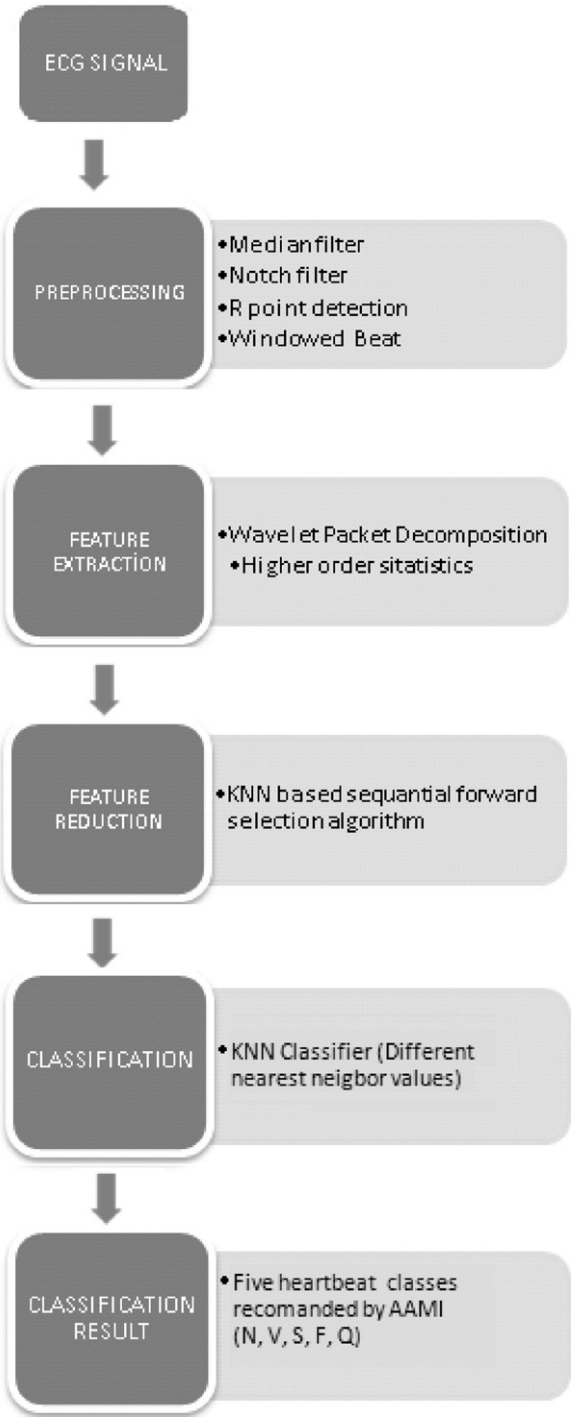

Fig. 1 – Block diagram of the constructed classification system.

2. Materials and methods

In this section the ECG data acquisition, pre-processing and feature extraction methods used in the proposed automated recognition system are described in detail. The general block diagram of the constructed system is shown in Fig. 1.

2.1. *Data acquisition*

The source of the ECG records used in this study is PhysioNet Database [36] which provides a set of over 4000 long-term holter recordings that were obtained by the Beth Israel Hospital Arrhythmia Laboratory between 1975 and 1979. Database contains 48 records sampled at 360 Hz. Each of the 48 records is slightly over 30 min-long. The subjects were 25 men aged 32–89 years old and 22 women aged 23–89 years old.

An ECG signal occurs as a result of the electrical activity within the heart which leads to cardiac muscle contraction. A typical ECG signal consists of P-wave, QRS complex, and T-wave. The depolarization of the atria causes the P-wave. The