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Wavelet-Based Classification of Myocardial Ischemia, Arrhythmia, Congestive Heart Failure and Sleep Apnea

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***Abstract*—**This paper presents wavelet based classification of various heart diseases. Electrocardiogram signals of different heart patients have been studied. Statistical natures of electrocardiogram signals for different heart diseases have been compared with the statistical nature of electrocardiograms for normal persons. Under this study four different heart diseases have been considered as follows: Myocardial Ischemia (MI), Congestive Heart Failure (CHF), Arrhythmia and Sleep Apnea. Statistical nature of electrocardiograms for each case has been considered in terms of kurtosis values of two types of wavelet coefficients: approximate and detail. Nine wavelet decomposition levels have been considered in each case. Kurtosis corresponding to both approximate and detail coefficients has been considered for decomposition level one to decomposition level nine. Based on significant difference, few decomposition levels have been chosen and then used for classification.

***Keywords*—**Arrhythmia, congestive heart failure, discrete wavelet transform, electrocardiogram, myocardial ischemia, sleep apnea.

I. Introduction

HEART diseases have direct influence on electrocardiogram (ECG) signals [1]-[3]. In this regard, different modelling and mathematical diagnosis techniques have been introduced in recent years [4]-[6]. In past, diagnosis of ECG has been observed in time domain. Gradually, many frequency domain methods have been observed for ECG study. However, in time and frequency domain, ECG signals are found non-stationary. Therefore, in many recent studies, time-frequency domain based mathematical tools are found to be effective in the assessment of ECG signals as well as in the assessment of heart diseases. In time-frequency domain, wavelet based analysis has been found effective to deal with non-stationary signals. This work deals with discrete wavelet transformation (DWT) based analysis of ECG signals [7]-[10] for diagnosis different heart diseases. Four common heart diseases i.e., MI [11], CHF [12], Arrhythmia [13], Apnea [14] have been considered in this work. Wavelet decomposition based analysis of ECG signal for MI has been described in [11]. Similarly, detail analysis for CHF has been described in [12], for Arrhythmia in [13] and for Apnea in [14]. The analysis described on those works are done using mother wavelet 'db4' and coefficients obtained, mainly, be categorized as (a) approximate coefficients based assessment (b) detail coefficients based assessment. In this work, kurtosis parameter based outcomes of [11]-[14] have been compared as a whole for classification four heart diseases from normal and among themselves. Then based on the observation, best decomposition level(s) have been selected.

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II. Parameter Comparison

A. Data Collection

Data for ECG signals of different heart patients have been collected from well-known database physionet.org [15]. Heart diseases considered in this work are MI [11], CHF [12], Arrhythmia [13], Apnea [7].

MI refers to reduced blood flow to our heart preventing it from receiving enough oxygen. It occurs due to partial or complete blockage of heart's arteries (coronary arteries). A sudden, severe blockage of a coronary artery may be dangerous causing heart attack.

Sometimes heart pumps inaccurately and inefficiently due to gradual accumulation of fluid surrounding the heart. It is commonly referred as CHF. Among different types of heart diseases CHF is severe one which may sometimes lead to the death of the patient.

Arrhythmia refers to the problems with the rate or rhythm of our heartbeat which means that heart beats too quickly, too slowly, or with an irregular pattern. If the heart beats faster than normal, it is called tachycardia. If the heart beats too slowly, it is called bradycardia. The most common type of Arrhythmia is atrial fibrillation, which causes an irregular and fast heart-beat.

Sleep Apnea is a serious breathing disorder that occurs when a person's breathing is interrupted during breathing. People with sleep Apnea stop breathing repeatedly during their sleep, means the brain and rest of the body may not get enough oxygen. If left untreated, sleep Apnea can result a number of health problem including high blood pressure, stroke, heart-failure, irregular heart-beats, heart-attacks, depression, etc.

Work flow has been shown in Fig. 1. The signal has been denoised by passing it through well-known filters like Savitzky-Golay FIR filter using MATLAB. This work deals with time – frequency domain approach of ECG signals. As ECG signals are non-stationary in nature, time-frequency domain analysis has been considered in this work and accordingly wavelet decomposition is performed. Each set of signal is decomposed up to 9th level with the help of mother wavelet "db-4".

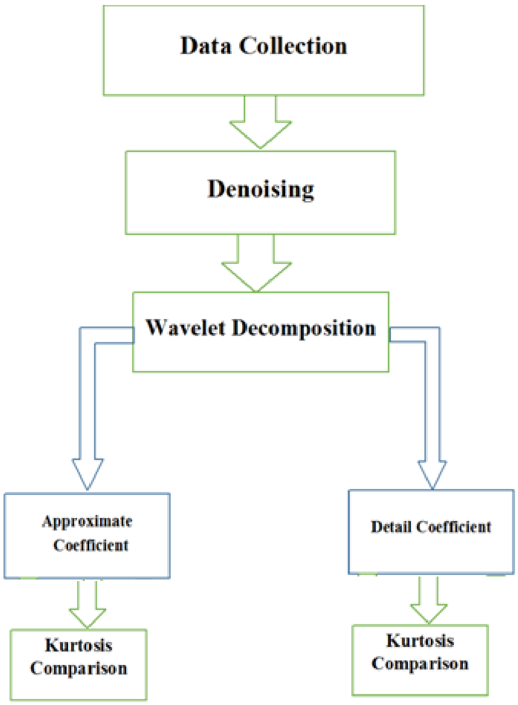

Fig. 1 Work flow diagram

At each level Approximate and Detail coefficients are determined. Natures of those coefficients have been studied by their kurtosis values. Kurtosis refers to a statistical nature used to verify whether data set are peaked or flat relative to a normal distribution; data set have a peak or a flat top near the mean if they have high or low kurtosis value respectively. At the end, comparative study has been carried out with respect to above said four heart diseases. Based on outcomes, an algorithm has been proposed.

B. Kurtosis of Approximate Coefficient

Kurtosis of approximate coefficients [3], [4] for MI, CHF, Arrhythmia and Apnea has been compared with that of normal healthy person with respect to wavelet decomposition levels (DWT) as shown in Fig. 2. It shows that values of KA are distinctly different at DWT level 1, 2 & 3 and therefore KA at DWT level 1, 2 and 3 may be used for classification of these diseases.

C. Kurtosis of Detail Coefficient

Kurtosis of detail coefficients for MI, CHF, Arrhythmia and Apnea have been compared with that of normal healthy person with respect to wavelet decomposition levels (DWT) as shown in Fig. 3. It shows that values of KD are distinctly different at DWT level 1 and therefore, KD at DWT level 1 may be used for diagnosis of these diseases.

III. Level Selection

Based on the comparison presented in Section II, few DWT levels from total 9 DWT level have been selected and corresponding parameter values have been compared. From Fig. 2 of Section II, DWT levels 1, 2 and 3 have been selected and corresponding parameters values have been compared by bar chart as shown in Fig. 4. Bars shown in these figures are different with respect to height for different diseases and also they are different from normal values.

From Fig. 3 of Section II, DWT levels 1 has been selected and corresponding parameters values have been compared by bar chart as shown in Fig. 5. Bars shown in these figures are different with respect to height for different diseases and also they are different from normal values. However, the difference between the height of the bar for CHF and Arrhythmia is small.

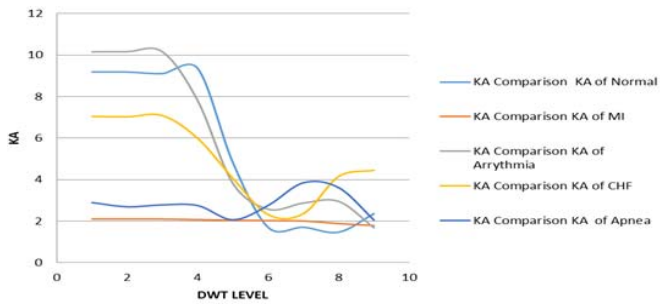

Fig. 2 KA vs. DWT Level for MI, CHF, Arrhythmia, Apnea patients and normal person

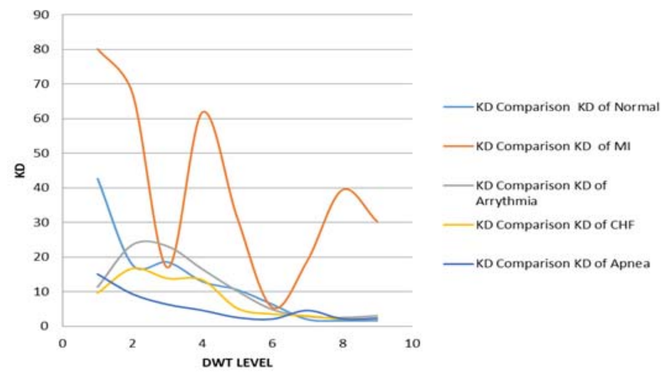

Fig. 3 KD vs. DWT Level for MI, CHF, Arrhythmia, Apnea patients and normal person

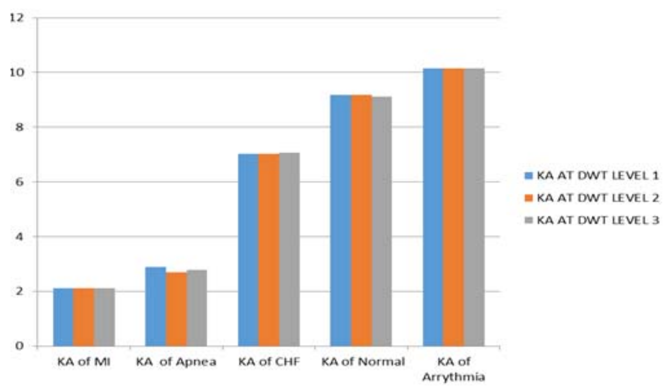

Fig. 4 KA at DWT Level 1, 2 and 3 for four diseases

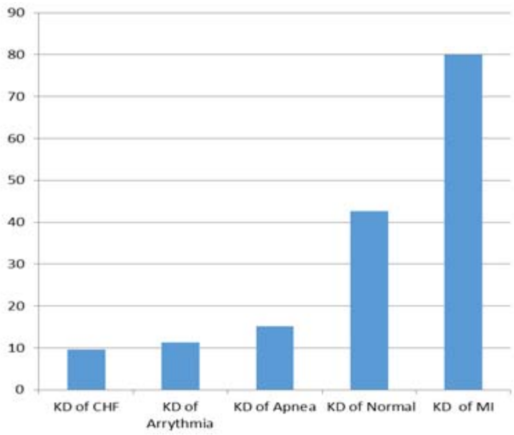

Fig. 5 KD at DWT Level 1 for four diseases

Therefore, from the observation of Figs. 2 & 4, level 1, 2 and 3 have been selected for kurtosis of approximate coefficients (KA) and from the observation of Figs. 3 & 5, level 1 has been selected for kurtosis of detail coefficients (KD). The selection made for KA and KD has been presented in Table I.

TABLE I
BEST DWT LEVEL SELECTION

Parameter	Best level(s)
KA	1, 2, 3
KD	1

TABLE II
BEST PARAMETER SELECTION

Option No	Number of parameter that can be used	Parameters
1	2	KA (1,2,3), KD (1)
2	1	KA (1,2,3)

IV. Parameter Selection and Algorithm

Based on the difference observed for different parameters for different diseases and normal values as shown in Figs. 4 and 5, KA (1,2,3) is considered best and comparatively KD (1) is found less suitable. Selected best parameter have been presented in Table II. Therefore,

- If diagnosis of heart diseases all two parameters are used, then, KA (1,2,3), KD (1)
- If diagnosis of heart diseases single parameter is used, then, KA (1,2,3) will be chosen.

Accordingly, an algorithm has been proposed for diagnosis of heart diseases as follows:

a. Capture ECG Signal of the person under study.
b. Perform wavelet decomposition with the help of mother wavelet “db-4”.
c. Determine approximate and detail coefficients.
d. Calculate Kurtosis of approximate coefficients for DWT levels 1, 2 and 3 i.e. KA (1, 2 and 3) and Kurtosis of detail coefficients for DWT level 1 i.e., KD (1).
e. Perform diagnosis or classification.

V. Conclusion

In this paper, wavelet based classification of various heart diseases has been presented where observations of statistical behavior of ECG signals for different heart diseases have been compared with the statistical nature of ECG for normal persons. Four heart diseases have been considered as follows: MI, CHF, Arrhythmia and Sleep Apnea and corresponding nature of ECG for each case has been considered in terms of kurtosis values of two types of wavelet coefficients. Among nine wavelet decomposition levels, first, second and third levels of approximate coefficients and first level of detail coefficients have been chosen and corresponding kurtosis values have been utilized for classification of heart diseases.

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