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Comparison of Normal, Ventricular Tachyarrhythmic and Atrial Fibrillation Electrocardiograms using Scatter Plots

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Abstract- Ventricular tachyarrhythmia and atrial fibrillation are cardiac diseases in which the electrocardiogram shows occurrence of ventricular tachycardia, flutter and fibrillation. In this paper a comparison has been shown between the RdR maps of the RR intervals of normal and arrhythmic ECGs. RdR maps are a scatter plot of RR intervals and change in the RR intervals of ECGs. This plot has been chosen because of its computational simplicity.

Keywords-ventricular tachyarrhythmia; atrial fibrillation; electrocardiogram; tachycardia; flutter; fibrillation; RR intervals

I. INTRODUCTION

Electrocardiogram or ECG is a well known bio signal for diagnosing cardiac diseases. It is popular because of its acquisition being non-invasive and devoid of any harmful side-effects.

In order to diagnose diseases it is important to know the ECG waves showing normal condition of heart. This wave consists of certain parts named as the P wave, PR interval, QRS complex, ST segment, T wave, QT interval and then the infrequent presence of U wave. The sino- atrial node or the SA node is positioned on the left atrium and this initiates the electrical signal causing atrial depolarisation. Although the atrium is anatomically divided into two parts, electrically they function as one part. Atria have very little muscle and produce a wave of small amplitude called the P wave. The PR segment is the subsequent part after the P wave and occurs as the electrical impulse is conducted through the atrio-ventricular node or the AV node, bundle of His and Purkinje fibres. The PR interval can be defined as the time between the onset of atrial depolarisation and the onset of ventricular depolarisation. After the PR interval, QRS complex occurs. This complex is generated by the depolarisation wave which travels through the interventricular septum via the bundle of His and bundle branches and reaches the ventricular myocardium via the Purkinje fibre network. The impulse first depolarises the left side of the septum, and then spreads towards the right. The left ventricle has larger muscle mass and thus its depolarisation dominates the ECG wave. The QRS complex ends at the J point and from here starts the ST segment. The ST segment which lies between the J point and the onset of the T wave, represents the period between the end of ventricular depolarisation and repolarisation. The T wave is the result of ventricular repolarisation. This wave in a normal ECG is asymmetrical as the first part of this wave is more gradual than the subsequent part. The QT interval is measured from the beginning of the QRS complex to the end of the T wave. Measurement of this interval is done by taking into account the heart rate as this interval elongates as heart rate decreases. The last part of the ECG is the U wave which is found just after the T wave ends. It is a small deflection and generally upright [1-2].

This paper looks at the difference in the patterns of the scatter diagram of RR interval versus dRR interval in diseased ECG as compared to normal sinus rhythm. RR intervals are found out from the ECGs after QRS detection using the established Pan Tompkins' algorithm [3-4]. The reason for plotting the RR interval versus dRR interval plot is because of its' computational simplicity [5]. Computational simplicity is useful in case of automated detection of arrhythmia from ECGs using implantable devices like loop recorder or chronic implantable monitors (CIM) [6]. For this paper the diseased data has been taken from PhysioNet. The algorithm has been run on ten ventricular tachyarrhythmic data named cu01 to cu10 [10] and on another ten atrial fibrillation data named n01 to n10 [11].

The ventricular tachyarrhythmic data available in Physionet, were passed through an active second order low-pass Bessel filter of cut-off frequency 70 Hz, and were digitised at 250 Hz with 12-bit resolution over a 10 V range (10 mV nominal relative to the unamplified signals). Each data is approximately 8.5 minutes in duration. These data show the presence of sustained

ventricular tachycardia, ventricular flutter and ventricular fibrillation [10].

The atrial fibrillation data, also from PhysioNet are approximately of one minute each in duration and have been sampled at 128 samples per second. These data segments were extracted from long term ECG recordings [11].

Ventricular fibrillation is a serious condition of the heart which may lead to stoppage of the heart if untreated. Precursor of fibrillation is often ventricular tachycardia or flutter. So it is important to detect flutter and tachycardia in the ECG. Ventricular tachycardia is defined as three or more ventricular extrasystoles in succession at a rate of more than 120 beats per minute. The tachycardia may be self terminating but is described as "sustained" if it lasts longer than 30 seconds [2]. This kind of tachycardia falls under broad category tachycardia which maybe of ventricular or supraventricular in origin but is mostly ventricular. In ventricular tachycardia the sequence of cardiac activation is altered, and the impulse no longer follows the normal intraventricular conduction pathway. As a consequence, the morphology of the QRS complex is bizarre, and the duration of the complex is prolonged [2].

Atrial fibrillation is caused by multiple activations sweeping around the atrial myocardiogram. In an electrocardiogram it is seen as a wavy, irregular baseline made up of fibrillation waves. It is a combination of absent P waves, fine baseline fibrillation base oscillations and irregular ventricular complexes [2].

II. PROCEDURE

A. Filtering using Pan Tompkins' algorithm

In this algorithm, the raw data obtained as shown in Fig. 1, Fig. 3 and Fig. 5 are passed through the band pass filter, which is the combination of a low pass filter and then a high pass filter [3-4]. The difference equations are as shown.

The difference equation of low pass filter [4],

$$y(nT)=2y(nT-T) - y(nT-2T) + x(nT) - 2x(nT-6T) + x(nT-12T) \quad (1)$$

The difference equation of high pass filter [4],

$$y(nT)=y(nT-16T) - \frac{1}{32}[y(nT-T) + x(nT) - x(nT-32T)] \quad (2)$$

Then the derivative of the band pass filtered signal is obtained and as in the Pan Tompkins algorithm. Squaring of the derivative signal shows the QRS complexes. In the next block a moving point integral is used. The difference equations of derivative, squaring and moving point integral are as shown.

Difference equation of derivative [4],

$$y(nT) = \frac{1}{8}[2x(nT) + x(nT-T) - x(nT-3T) - 2x(nT-4T)] \quad (3)$$

Equation for squaring [4],

$$y(nT)=[x(nT)]^2 \quad (4)$$

Difference equation of moving point integral [4],

$$y(nT)= \frac{1}{N}[x(nT-(N-1)T) + x(nT - (N-2)T) +\ldots+ x(nT)] \quad (5)$$

Here N is the number of samples in the width of the moving point integral.

B. RR interval versus dRR plot

After QRS detection has been done, RR intervals from the signal are extracted. This RR interval signal is again used to find out the dRR intervals, which are the difference between two consecutive RR intervals. A plot is made using these two signals, namely RR and dRR in the x-axis and y-axis respectively [5].

III. RESULTS AND DISCUSSION

A. Band pass filter of Pan Tompkins' algorithm

The band pass filter that has been used has been done by using a low pass filter and then a high pass filter in cascade [3-4]. The purpose of low pass filter is to suppress high frequency noise. This band pass filter for QRS detection algorithm reduces noise in the ECG signal by matching the spectrum of average QRS complex, eliminating noise due to muscle artefacts, 60 Hz power line interference, baseline wandering and T wave interference. QRS energy is maximised by the pass band of approximately in the 5 to 15 Hz range. The filter is an integer filter which has poles located such so as to cancel out the zeroes. The high pass filter is implemented by subtracting a first order low pass filter from an all pass filter with delay.

B. Derivative of Pan Tompkins' algorithm

To provide information about the slope of the QRS complex, differentiation of the band pass filtered signal is done. A five point derivative [4] is implemented using the transfer function as given in (3).

C. Squaring of Pan Tompkins' algorithm

After derivative, the signal is to be squared. This is a non- linear processing and it is done to get all positive values from the signal. Point by point squaring of the

signal obtained from the differentiator is implemented [4].

D. Moving Integrator of Pan Tompkins' algorithm

The slope of the R wave is not the absolute way to detect QRS complexes in an ECG. There may be many long duration and large amplitude QRS waves in the ECG which is abnormal. Only slope of R wave cannot detect these waves. So a moving window integrator is used so that these waves can well be detected and the outputs from this block are shown in Fig. 2 for the normal data, Fig. 4 for ventricular tachyarrhythmic data and Fig. 6 for atrial fibrillation data.

E. RR intervals versus dRR intervals plot

The plot of RR (in the x-axis) intervals and dRR intervals (in the y-axis) is different from conventional Lorenz's plot which uses either RR intervals or dRR intervals [6-9]. This plot is named as RdR plot [5]. In this paper RdR plot has been plotted after extracting the RR intervals and dRR intervals from the QRS detected signal of the electrocardiogram data. This plot shows both the heart rate interval and the change in the heart rate interval in the same plot. RdR plots can then be used for cardiac rhythm classification [5]. The RdR plots for normal and ventricular tachyarrythmic and atrial fibrillation electrocardiograms are shown in Fig. 7, Fig. 8 and Fig. 9 respectively. The diseased ECG shows the data inclined towards the lower right direction as shorter RR intervals tend to have negative dRR values [5].

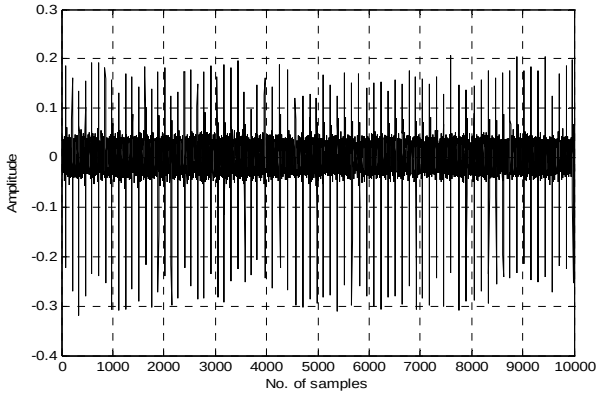

Figure 1. Raw data of normal ECG

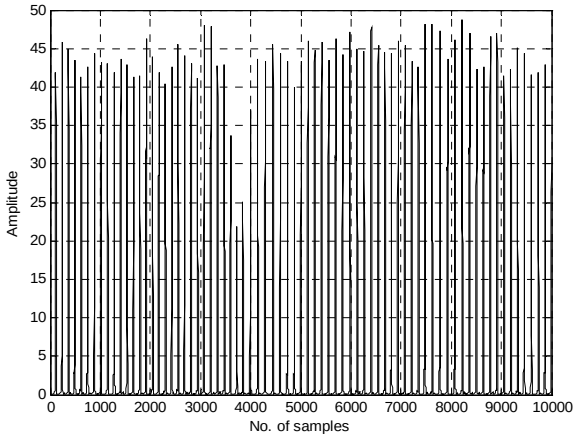

Figure 2. QRS complexes of normal ECG

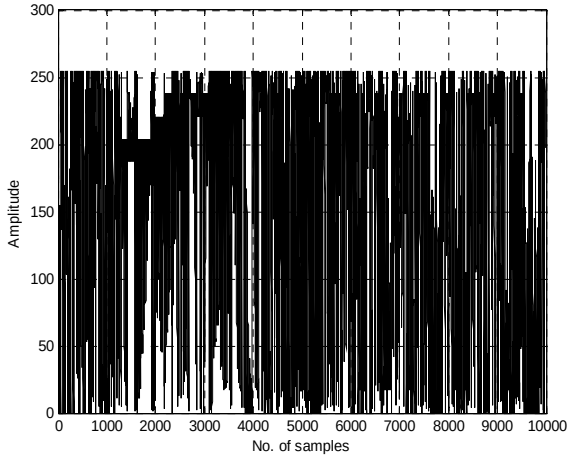

Figure 3. Raw ventricular arrhythmic ECG (data cu04)

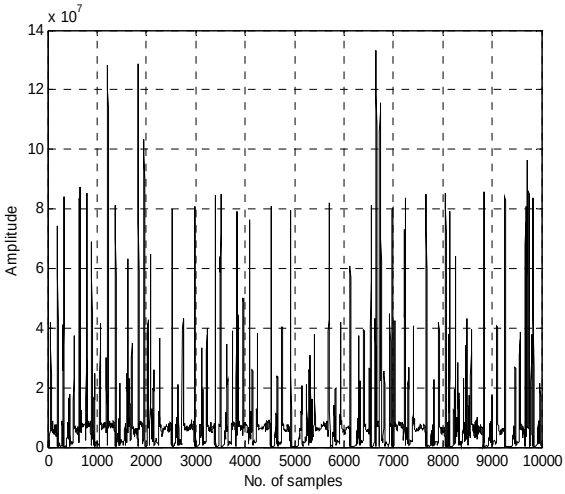

Figure 4. QRS complexes of diseased ECG (data cu04)

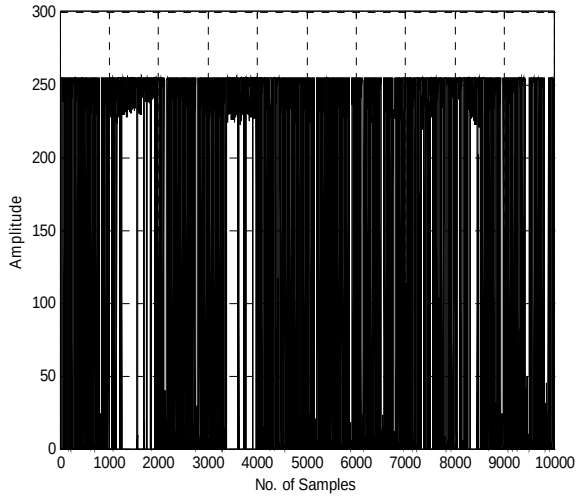

Figure 5. Raw atrial fibrillation ECG (data n01)

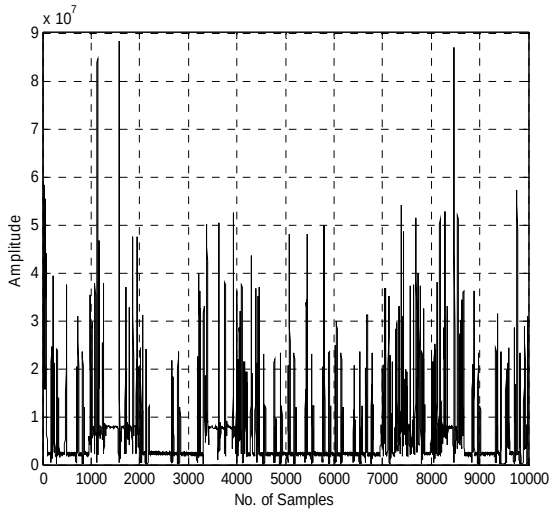

Figure 6. QRS complexes of diseased ECG (data n01)

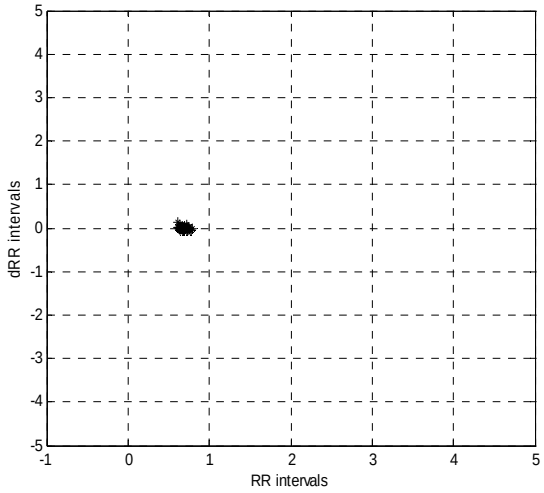

Figure 7. RdR plot of normal ECG

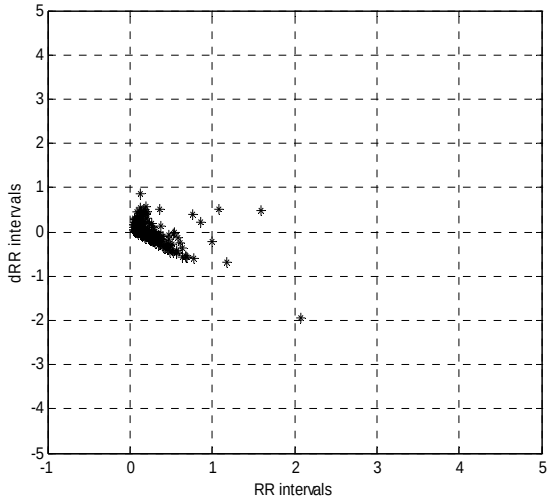

Figure 8. RdR plot of diseased ECG (data cu04)

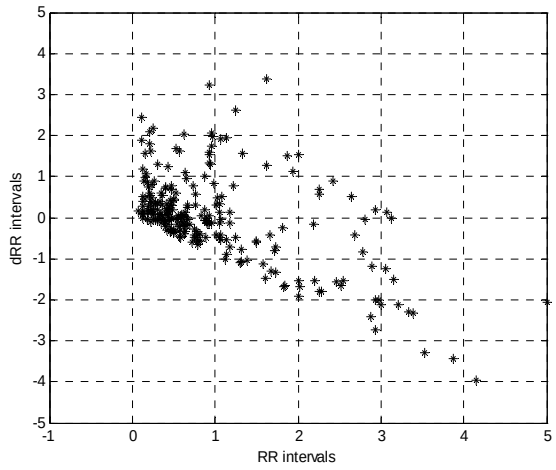

Figure 9. RdR plot of diseased ECG (data n01)

CONCLUSION

It can be observed from the figures, distinct spatial distributions are occurring in the RdR plots of normal and arrhythmic Electrocardiograms. In the normal ECG, as the RR intervals as well as the change in the RR intervals are regular the scatter plots are confined to a very small region as shown in Fig. 7. But in case of ventricular tachyarrhythmic ECG, because of the presence of the sustained ventricular tachycardia and flutter, there are irregularities in the RR intervals and consequently irregularities in the change in the RR intervals. So they show a 'spread out' region in the RdR plot, as shown in Fig. 8. In Fig. 9 a wide region of points can be observed in the RdR plot because of the presence of atrial fibrillation. The RdR plots of the two diseases show difference from the RdR plot of normal ECG and also between themselves. So it can be concluded that RdR plots obtained from Electrocardiograms can be considered an effective way to differentiate between normal and arrhythmic Electrocardiograms.

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