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Study of Hypocalcemic Cardiac Disorder by Analyzing the Features of ECG Signal Using DWT Technique

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Abstract - *Heart diseases are one of the most fatal diseases leading to deaths if they are not diagnosed and treated properly on time. The electrical signals (ECG signals) from the heart are monitored for detecting the cardiac disorders and heart diseases. The ECG signals are significantly affected by the various noises produced by the electronic devices used for monitoring the ECG signals. It is very essential to develop an effective de-noising technique to generate accurate ECG signals to monitor diseases in heart patients. Further the strategies are development and designed for the detection of hypocalcaemia from the QRS complex of the ECG signal using wavelet transform technique. The paper presents the effective de-noising technique and statistical parameters like Mean Square Error (MSE), Root Mean Square Deviation (RMSD) and Percentage Deviation (PD) are estimated for the ECG signal which gives the amount of error in the ECG signal. The comparison between parameter is made to distinguish between healthy person and the cardiac patients.*

Key Words: **AD, Hypocalcemia, DWT, ECG, Mean, MSE, PD, RMSD.**

1. INTRODUCTION

The electrical wave duration decides whether the electrical activity is normal, slow or irregular. Range of the frequencies of an ECG signal is 0.05–100 Hz. ECG signal has five peaks that are named as P, Q, R, S and T. Another peak called U is also seen in some cases[1].

P, QRS and T are the waves present in ECG signal. The wave corresponds atria depolarization, ventricular depolarization, and ventricular re-polarization. ECG signal showing various peak intervals is as shown in Figure 1. ECG signal has three segments namely, PR segment, ST segment and TP segment. Normally, P-R interval is in the range of 0.12 to 0.2 second. Range of QRS interval is from 0.04 to 0.1 second and the Q-T interval is less than 0.42 second[2]. Usually ECG signals are contaminated by various kinds of noise. Hence proper de-noising of the ECG signal is carried out.

Wavelet transform is applied to the de-noised ECG signal to obtain various peaks in the ECG signal like Q, R and S-peak. From the peaks the average rise time and average fall time of ECG signal is determined. From the detected Q, R and S-peaks the QRS complex is determined. With the help of detected QRS complex, the interval between QRS complex of ECG signal is calculated.

After the calculation of these interval, hypocalcemia is determined[4]. From the resulting value of QRS complex it is detected whether the patient is normal or not. Patient is normal if he has a QRS complex within 0.1 second other than this range it is seen that hypocalcaemia is present.

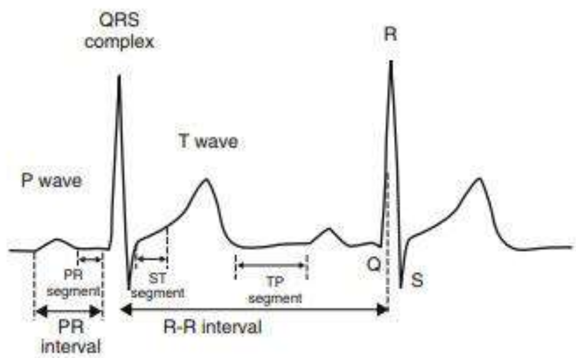

Fig -1: ECG signal showing various peak intervals[3].

Mean value is determined for the occurrence of QRS complex of ECG signal obtained from the Q, R and S-peaks. From the determined mean value and sum of squared difference of occurrence of the interval the value of RMSD is calculated. Deviation of the value from mean value is determined. Average Deviation (AD) from mean is calculated. From the values of mean and average deviation from mean the Percentage Deviation (PD) is calculated.

2. LITERATURE SURVEY

Muhammad Arzaki et al. 2017 [5], describes about the Mean Square Error (MSE). MSE is a method to evaluate the difference between actual and predicted data.

Modjtaba Rouhani et al. 2009 [6], describes about the RMSD. RMSD is the square root of average of squared errors. It is a non negative value. Lower RMSD yields better results.. It is a measure of accuracy to compare errors.

Nicolae Marius Roman et al. 2015 [7], describes about hypocalcemia. The condition in which there is lower levels of calcium in plasma. If the ECG signal has prolongation of QT interval because of lengthening of ST segment which is directly proportional to hypocalcaemia.

M. J Burke et al. 2009 [8], describes about the average rise and fall time for the ECG signal. Average rise time is the average time it takes for the edge of the pulse to raise from its minimum to maximum value (Q-peak to R-peak). Average fall time is the average time it takes for the edge of the pulse to move from its maximum to minimum value (R-peak to S-peak).

Hudson et al. 2017 [9] presented, describes about the Savitzky Golay filter. Peak shape preservation property of the Savitzky Golay filters are attractive in applications such as ECG signal processing. The major advantage of this method is the preservation of important features of the original time series, like relative widths and heights. SG filter fits a polynomial in a window of points around each sample point using least squares fitting.

Lim Choo Min et al. 2007 [10], describes the steps in ECG signals analysis.

3. PROPOSED METHODOLOGY

The proposed methodology is based on the technique to detect hypocalcemia using DWT based on QRS complex detection. RMSSD and Percentage deviation are determined for normal and abnormal signal. Original input signals are taken from MIT-BIH Database directory of ECG signals from www.physionet.org. Flow chart is as shown in Figure 2 which depicts the steps involved in the detection which are as follows:

3.1 De-noising of ECG signal

The derivative based approach amplifies high frequency noises, which leads to high difference signals due to noise. Therefore, initially smoothing and filtering of ECG signal is carried out to eliminate low frequency noises in ECG signal. Smoothing of the signal is done using SG filtering. Smoothened ECG signal is FIR filtered, hence de-noised signal is obtained.

3.2 Detection of Q, R and S-peaks

Physiologic signals are frequently non stationary which means that their frequency content changes over time. Signals are often localized in time and frequency, analysis and estimation are easier when working with reduced representations. DWT is used to find the Q-peak, R-peak and S-peak from the ECG signal. DWT transformation is as given by the equation 1.

$$Tm,n = \sum_{-\infty}^{\infty} x(t)\, \Psi_{m,n}(t) \quad (1)$$

Where, $x(t)$ is the signal to be analysed,
$\Psi_{m,n}(t)$ is the mother wavelet.

All the wavelet functions used in the transform are derived from the mother wavelet through wavelet translation (n) and scaling (m).

3.3 Calculation of Average Rise Time (ART) and Average Fall Time (AFT)

ART and AFT are calculated from the detected Q, R and S peaks of the de-noised ECG signal. ART and AFT are calculated in seconds. ART is obtained by finding average of the duration between Q and R-peaks. Average Fall Time is obtained by finding average of the duration between R and S-peaks. Average QRS complex is determined from Q, R and S-peak.

3.4 Detection of hypocalcemia

From the obtained Q, R and S-peaks of ECG signal, QRS complex of ECG signal is determined. From these complexes, the time interval between their occurrences is determined. Duration between the QRS complex is calculated in seconds. If the QRS complex duration is below 0.1 second then it is a normal condition. If the QRS complex duration is above 0.1 second then hypocalcemia is detected.

3.5 Calculation of MSE

MSE is defined as the average squared difference between the estimated values and what is to be estimated. MSE is a non negative value and values closer to zero are better. Smaller value of Mean Square error gives better results. MSE is given by equation 2.

$$MSE = \frac{1}{n}\sum_{i=1}^{n}(Y - Y'_i)^2 \quad (2)$$

Where, MSE is the Mean Square Error.
Y is the mean value.
Y' is the obtained value.
n is the number of samples.

3.6 Calculation of RMSD

RMSD is defined as the average of squared errors. RMSD is always a non negative and a value of zero indicates a perfect fit to data which is an ideal condition. RMSD values closer to zero indicates better results. Lower RMSD is better than higher value of RMSD. Thus larger errors have a disproportionately large effect on RMSD. RMSD is given by the equation 3.

$$RMSD = \sqrt{MSE} \quad (3)$$

Where, *MSE* is the Mean Square Error.
RMSD is the Root Mean Square Deviation.

3.7 Calculation of Percentage Deviation (PD)

Percentage Deviation (PD) refers to how much the mean of a set of data differs from a known or theoretical value. Mean and Average Deviation (AD) is used to find percentage deviation. Mean is defined as the ratio of sum of values of all data points to the number of data points. Average deviation gives the average variation of the data points from the mean value. Percentage deviation is given by the equation 4.

$$PD = \frac{Average\ Deviation}{Y} \text{ X } 100 \quad (4)$$

Where, *PD* is the Percentage Deviation.
Y is the mean value.

The value of MSE, RMSD and PD are the measures for calculation of accuracy which gives the amount of error present in the ECG signal.

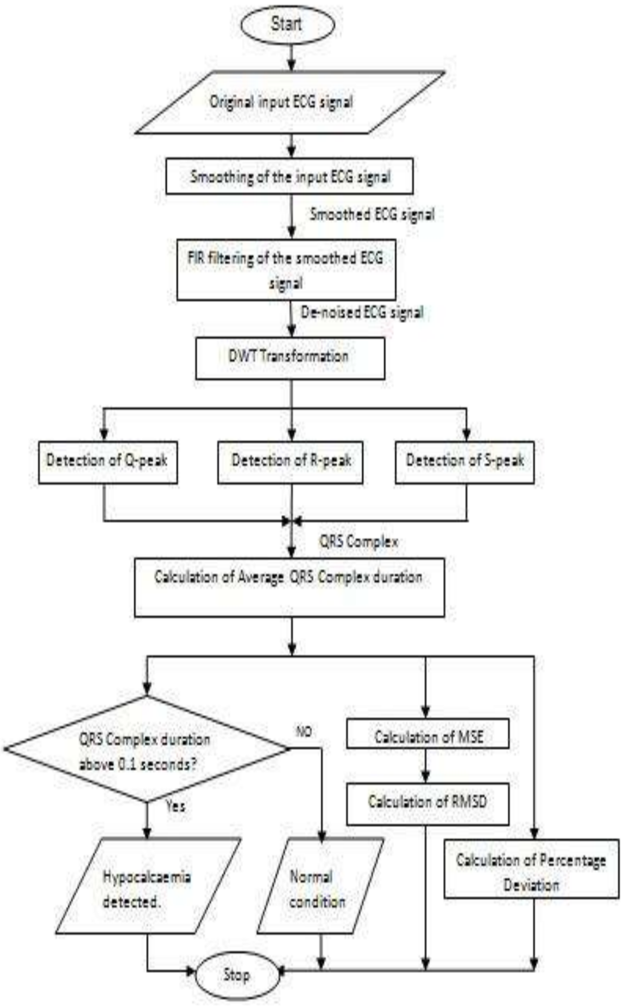

Fig -2: Flow chart.

4. RESULTS AND DISCUSSION

Original ECG signals are taken from MIT-BIH database directory of physionet. These signals are smoothened and filtered to remove low frequency noises present in the signal to obtain de-noised signal. Since ECG signal is non stationary, wavelet transform is applied to the de-noised ECG signal to obtain Q, R and S-peak which forms the QRS complex. From the obtained peaks, average QRS complex duration is determined. Depending on the value of average QRS complex duration, patients are classified as normal or hypocalcemic. If the average QRS complex duration is below 0.1 second then the condition is normal. If it is above 0.1 second then the condition is hypocalcaemia.

Three ECG signals MIT-BIH 200, MIT-BIH 203 and MIT-BIH 107 are used as test signals. The original and de-noised MIT-BIH 200, MIT-BIH 203, MIT-BIH 107 ECG signals are as shown in the Figure 3, Figure 6, Figure 9. The filtered noise and the R-peaks of MIT-BIH 200, MIT-BIH 203, MIT-BIH 107 ECG signal are as shown in the Figure 4, Figure 7, Figure 10. The S-peaks and Q-peaks of MIT-BIH 200, MIT-BIH 203, MIT-BIH 107 ECG signal is as shown in the Figure 5, Figure 8, Figure 11.

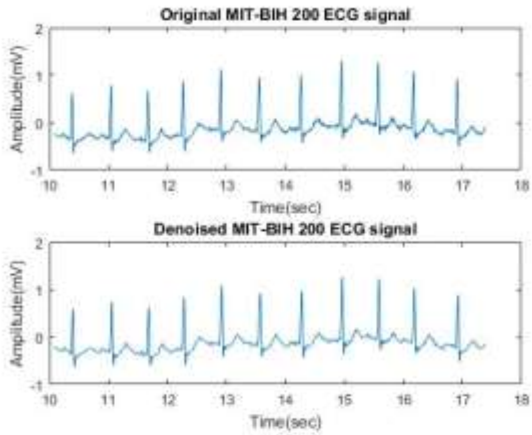

Fig -3: Original and de-noised MIT-BIH 200 ECG signal.

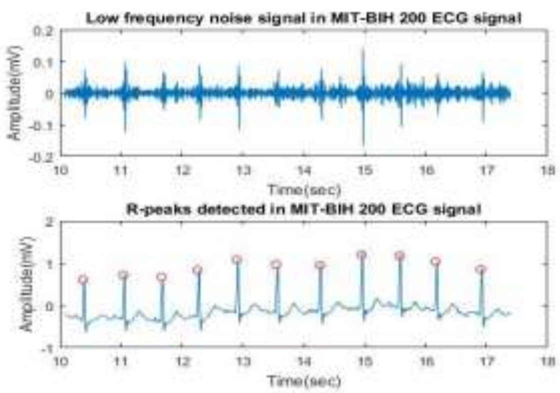

Fig -4: Filtered noise and the R-peaks of MIT-BIH 200 ECG signal.

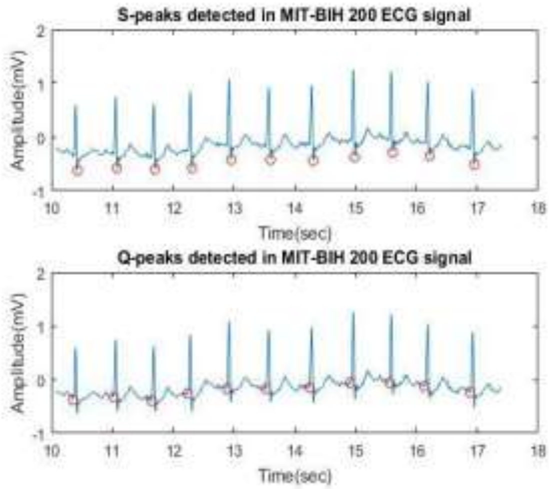

Fig -5: S-peaks and Q-peaks of MIT-BIH 200 ECG signal.

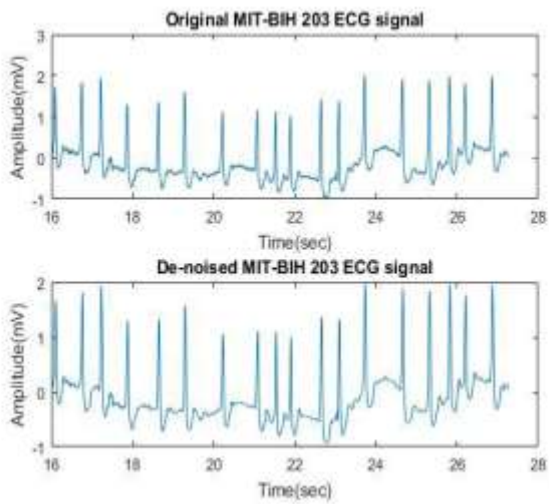

Fig -6: Original and de-noised MIT-BIH 203 ECG signal.

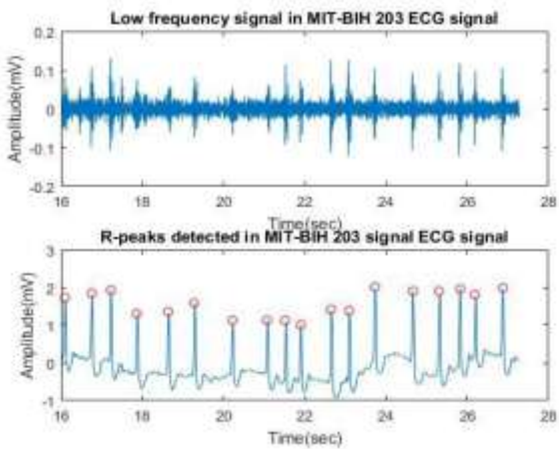

Fig -7: Filtered noise and the R-peaks of MIT-BIH 203 ECG signal.

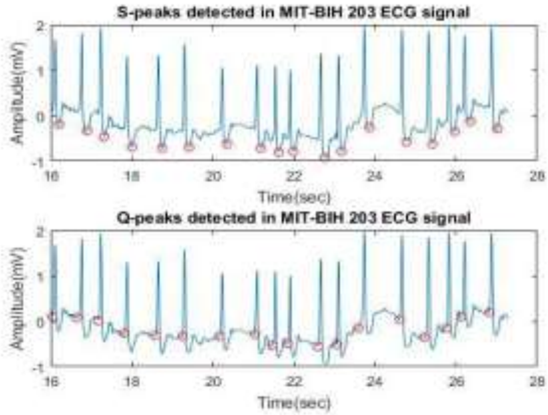

Fig -8: S-peaks and Q-peaks of MIT-BIH 203 ECG signal.

Various statistical analysis of the parameters are carried out for MIT-BIH 200, MIT-BIH 203 and MIT-BIH 107 ECG signals are as shown in the Table 1. Average QRS complex duration for MIT-BIH 200 ECG signal is 0.0702 second. Therefore the heart condition is normal. Average QRS complex duration for MIT-BIH 203 ECG signal is 0.1750 second. Therefore the heart condition is hypocalcaemia. Average QRS complex duration for MIT-BIH 107 ECG signal is 0.1775 second. Therefore the heart condition is hypocalcaemia.

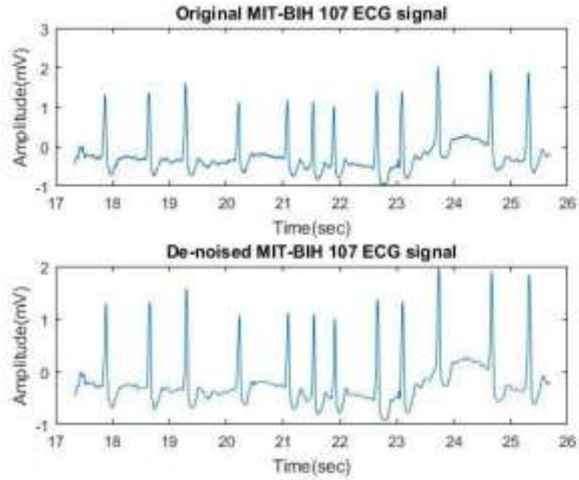

Fig -9: Original and de-noised MIT-BIH 107 ECG signal.

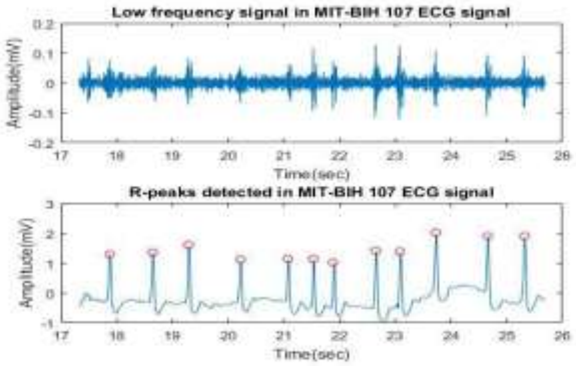

Fig -10: Filtered noise and the R-peaks of MIT-BIH 107 ECG signal.

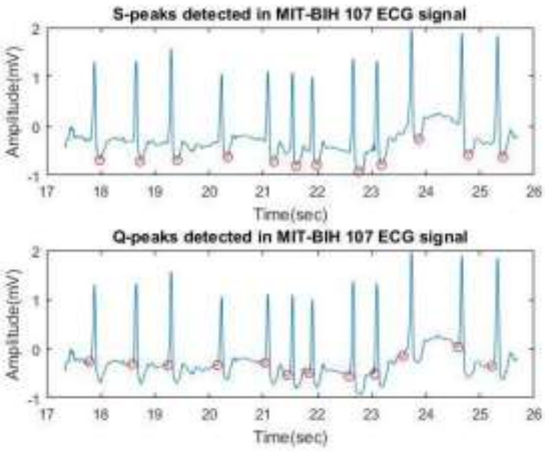

Fig -11: S-peaks and Q-peaks of MIT-BIH 107 ECG signal.

Table -1: Calculated values of various parameters of QRS complex for MIT-BIH 200, MIT-BIH 203 and MIT-BIH 107.

Parameters	For MIT-BIH 200	For MIT-BIH 203	For MIT-BIH 107
1) Average Rise Time for QRS complex	0.0409	0.0739	0.0750
2) Average Fall Time for QRS complex	0.0293	0.1011	0.1025
3) Average QRS Complex Duration	0.0702	0.1750	0.1775
4) Mean value	0.6530	0.6355	0.6755
5) Mean Square Error (MSE)	0.0019	0.0500	0.0381
6) Root Mean Square Deviation (RMSD)	0.0435	0.2336	0.1378
7) Average Deviation (AD)	0.0356	0.1416	0.1710
8) Percentage Deviation (PD)	5.4518%	8.9322%	10.5114%

5. CONCLUSION

ECG is a very useful bio-signal which is used by physicians for the purpose of diagnosing and monitoring heart disease and cardiac disorder. Therefore it becomes essential to examine ECG signal so as to detect chronic diseases in its early stages. ECG signals are prone to various noises. Therefore de-noising of the ECG signal is carried out where low frequency noises are removed. A method has been proposed to detect heart conditions. From the detected Q, R and S-peaks using wavelet transform the QRS complex and its duration is determined. Depending on this duration hypocalcaemia is detected. In MIT-BIH 200, normal condition is observed. Hypocalcemia condition is detected in MIT-BIH 203 and MIT-BIH 107 ECG signals. Statistical parameters are analyzed which are effectively used for distinguishing between the normal persons and cardiac patients. MSE, RMSD and Percentage Deviation (PD) for MIT-BIH 200 are less than that of MIT-BIH 203 and MIT-BIH 107 as a result of variation in the signal due to hypocalcemia.

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