Detection of Heart Abnormalities Using Signal Processing

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Abstract: **The heart is the center of life. It pumps and distributes blood to every other part of the body. Thus, it holds a strategic position in the body and must be in perfect condition at all times to perform these operations. The Electrocardiogram (ECG) is used to demonstrate the circuit activity of the heart. However, ECG signals can be difficult to interpret especially from non-health professionals. In this work, we developed a model that can detect and interpret the characteristics of an ECG signal, hence, identifying non-linearity of the heart. Fast Fourier Transform was used to filter our ECG readings dataset and remove unwanted signals, before the signals were used for classification and calculation of heart rate using peak values/intervals. The dataset contained about 218,000 ECG readings, including gender and age grades of the patients. Object Oriented Analysis and Design Methodology (OOADM) was adopted in this approach. The system was implemented using MATLAB software. The overall efficiency of the model is 95%, which outperforms other existing models. This system could be beneficial to the research community on signal processing.**

I. INTRODUCTION

Due to the gravely important functions of the heart in the human body such as pumping of blood, maintaining blood pressure etc, it is always important to ensure it is kept in the best condition possible at all time. The electrocardiogram (ECG) is a medical test that is used to detect cardiac or heart abnormalities. The ECG is measured in terms of a voltage against time graph of the electrical activity of the heart. The normal reading of the heart is 120 – 200 m/s. While the normal heart rate is 60 – 100 beats per minute. The ECG is also used to track some heart disorders such as reduced blood flow, high blood flow, delayed or fast beats per second etc. The ECG signal is generated by the expansion and contraction of the heart.

Interpreting or detecting the ECG signal can be a tedious task [1]. To overcome this limitation, we proposed fast and accurate classifier that simulates the diagnosis of the cardiologist to classify the ECG signals into normal and abnormal from a single lead ECG signal and better than other well-known classifiers.

The ECG signal is normally noisy therefore it is important to denoise the signal before applying the classification models to it. Some of the noises associated with ECG signal include Baseline Wander, Powerline interference, EMG noise and electrode motion [2]. While making a choice for a denoising technique, we should be concerned about retaining the validity of the signal after the noise has been removed.

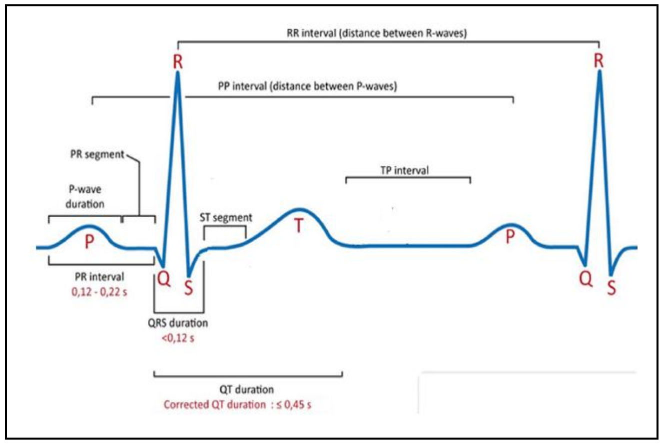

Fig. 1: ECG Curve for a Normal Heart [1]

This is because most techniques cause loss of signal during the denoising process. Hence, we adopted the Fast Fourier Transform (FFT) denoising tool. This tool converts a signal into individual spectral units thereby removing unwanted signals and providing frequency information about the signal.

Fuzzy logic and Neural Networks (NN) will be applied on denoised ECG signal dataset to classify the denoised signal using a binary classification approach as either normal or abnormal.

The major problem associated with the ECG signal is the complexity of the signal which makes it difficult to be interpreted or detected when an abnormal or non-linear signal is read from the heart. The aim of this research is to develop a model that can detect and interpret the characteristics of an ECG signal, hence, identifying non-linearity of the heart. We develop a classification model by using hybrid Fuzzy and Neural Networks for ECG signals. Train the model using Neural Networks and Implement using MATLAB simulation software.

II. RELATED WORKS

Hammad et al [1] proposed detection of abnormal heart conditions based on the characteristics of ECG. They developed an accurate classifier which simulated the cardiologist's diagnosis and classified the ECG signals as either normal or abnormal using a single lead ECG signal. Two NNs, Four SVMs and a KNN were used to design the classifier. They validated the algorithm using records from MIT-BIH arrhythmia database. The algorithm had a classification accuracy of 99%. However, they could not classify other types of abnormal ECG signals using their algorithm.

Dixit and Thorat [3] proposed ECG detection using controller. They presented the design of an ECG monitoring and heart rate measurement system based on ARM LPC2148 processor, with low cost amplifier, filter components coupled with a sophisticated microcontroller and LCD screen. However, they could not transmit the ECG signals using mobiles, signal transmitters or internet.

Millette and Baddour [4] proposed signal processing of heart signals for the quantification of non-deterministic events. The basis of the algorithm was the Johansen's algorithm for detection of cavitation in mechanical heart valve patients. They analytically demonstrated that the algorithm would quantify levels of non-deterministic energies as long as proper signal segmentation was performed so that all heart beats were superimposed as much as possible. However, they did not use any algorithm to denoise the signal before processing.

Zhang et al [5] presented a novel method of diagnosing heart disease based on deep learning ECG sign. They combined cardiology, signal processing and deep learning models to develop their method. They used wavelet transform and cardiology to transform the ECG signal into time frequency diagram, then classified the frequency diagram using deep convolution network. Their method achieved 0.87 F1-score. However, they could not experiment with a larger dataset and finer annotations.

Zhang et al [6] proposed an automated detection of cardiovascular disease by electrocardiogram signal analysis using deep learning. They trained a CNN to detect cardiovascular disease in ECG signals of over 259,789 signals collected from a tertiary care hospital. The system could diagnose over 17 different ECG abnormalities and normal ECG. The overall accuracy of the model was found to be over 95%. However, the credibility and interpretability of ECG signals using their model was low.

Nayak et al [7] presented a review of nonlinear dynamical system analysis of electrocardiogram signal. They reviewed contained a review of the nonlinear signal analysis methods, namely, reconstructed phase space analysis, Lyapunov exponents, correlation dimension, detrended fluctuation analysis (DFA), recurrence plot, Poincare plot, approximate entropy, and sample entropy along with their recent applications in the ECG signal analysis.

Diri and Kabari [8] proposed abnormal heart rate detection using signal processing. They adopted the Dynamic Software Development Methodology. The system was designed using Python programming language and ECG signals were acquired in the form of datasets. The signals were processed and important parameters like PQRST to detect heart abnormalities were extracted.

Kher and Gohel [9] proposed digital signal processor (Tms3200c6713) based abnormal beat detection form ECG signals. They presented a processor for the detection of the two types of Arrhythmia called premature ventricular contraction (PVC) and atrial fibrillation (AF). They applied morphological characteristics of Arrhythmia to differentiate the types. A correlation based algorithms and an amplitude based algorithm were applied to classify and detect the PVC and AF beats and evaluate their accuracies.

JAved et al [10] proposed a signal processing module for the analysis of heart sounds and heart murmurs. An electronic stethoscope was used to acquire the heart sounds which were later segmented into circles using spectral analysis of the heart instead of ECG signals. The features of the signal were extracted using a spectrogram. Extracted signals were fed to the MLP neural network trained to detect heart murmurs. On detection, the model classified the murmur into seven clsses depending on their timing within the cardiac cycle using Smoothed Pseudo Wigner-Ville distribution. The module has been tested with real heart sounds from 40 patients and has proved to be quite efficient.

Mayapur [11] proposed detection and classification of heart defects. They extracted the characteristics of the ECG and passed a random signal to check if the features or values determined fell within the specified range with the normal ECGs. If this condition returned a true value, the classified as normal ECG else, it was classified as abnormal ECG using Lead-II configuration. The major limitation of the work was the use of a small sample size for testing.

III. METHODOLOGY

In this study, object Oriented Analysis and Design methodology was adopted for the development of the system. The ECG dataset was gotten from KAGGLE dataset repository. The dataset contained the age, gender, and ECG reading of patients. The dataset was made up of about 218,000 records.

In the MATLAB workspace, two variables were created "sample 1" and "sample 2".

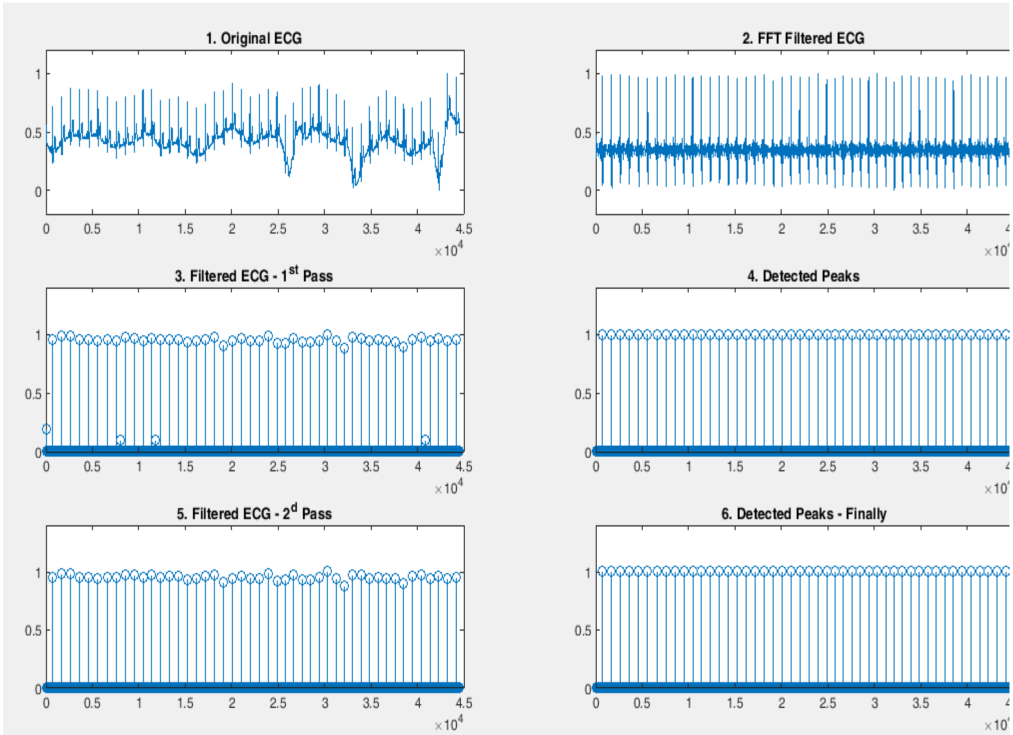

Fig. 1: Data Processing Outputs for Sample 1

i. Data Processing/ Noise Removal

During the data processing /noise removal stage, the unwanted/low frequency components were removed using the FFT tool.

This was achieved by using FFT to change the signal to frequency domain, removing the unwanted signals and converting back to the time domain. Next, the windows filter was used to find local maxima. Then the small values were removed while the significant values were stored, this is also called thresholding. The filter size was adjusted and the whole process was repeated. Figure 2 and 3 display the image processing outputs for the two data samples.

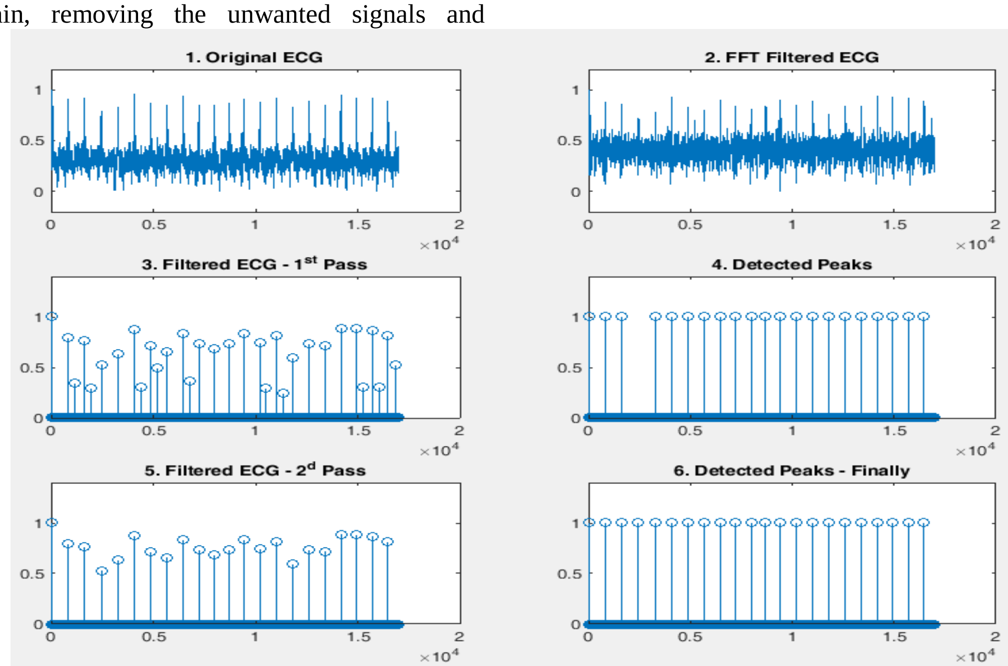

Fig. 2: Data Processing Outputs for Sample 2

In plots were divided into two columns and 3 rows to demonstrate each stage of the data processing for the two samples. The first plot shows the input data in form of ECG signal. The second plot displays the corrected ECG signal after removal of the low frequency components. The third plot shows the data after 1st filtering pass, the filter window is of default. The fourth plot shows detected peaks on this stage some peaks can be skipped. We analyzed the result of peak detection and optimize the filter window size. So the fifth plot contains the result of 2nd filtering pass. And the final plot contains the final results showing clear plots.

We included other analysis in our study and represented them in plots such as the histogram representing the distribution of ages and genders in our dataset. The plots are represented in figure 3 and 4

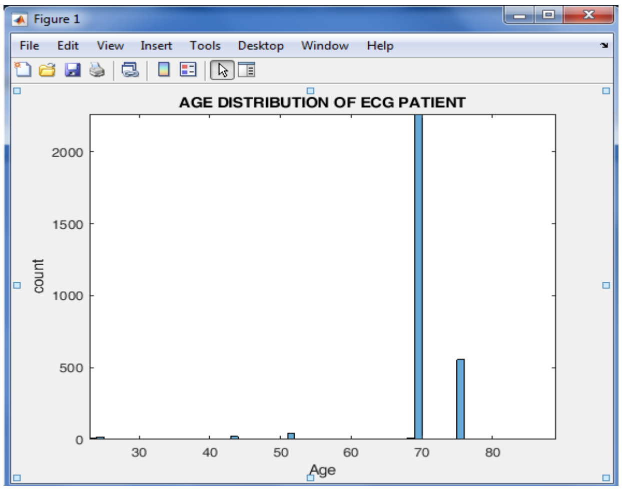

Figure 3: Age Distribution of ECG Patients

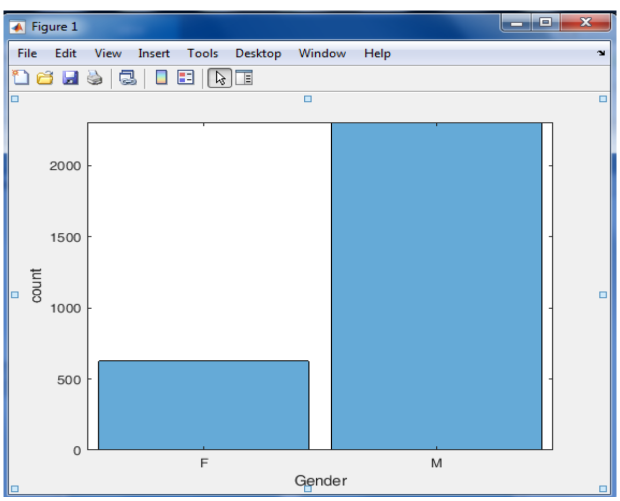

Figure 4: Gender Distribution of ECG Patients

IV. RESULTS AND DISCUSSION

The average distance between the R-R peaks also called R-R average is calculated using the following formula.

$$R - R\ Average = \frac{Distance\ \ between\ \ Ist\ \&\ Last\ Peaks}{Total\ \ No.\ of\ \ Peaks} \ldots\ldots\ldots\ldots(1)$$

The abnormality or normality of a heart is determined by the heart rate. The heart rate is calculated using the following formula.

$$Heart\ Rate = \frac{60 * Sampling\ \ rate}{R - R\ Interval} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

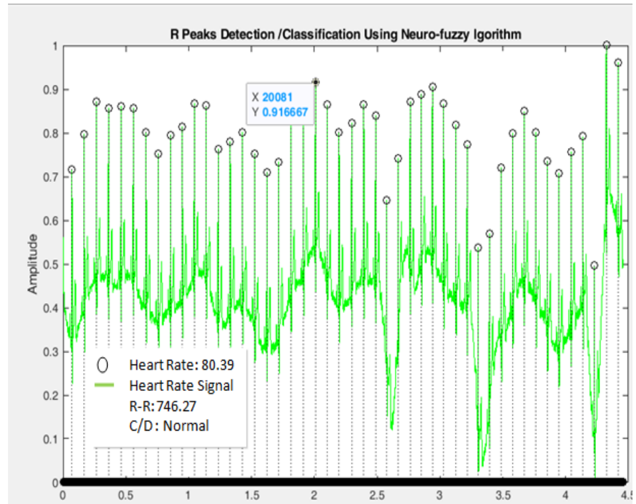

Figure 5: ECG R-R Peaks Detection for Sample 1

If the Heart Rate is below 60, it is classified as abnormal and the person as demonstrated in Figure 5. On the other hand, if the heart rate ranges from 60 to 100, it is classified as normal heart rate. The Fuzzy-Neural Network was used to perform the classifications on the plots.

The model classification and calculation of ECG signals were done in 5 seconds (timed by a stop watch). And the general performance of the model was 95%. This was gotten from evaluating the model using parameters like: Model efficiency (50%), Quality of Dataset (25%) and Time Complexity (20%).

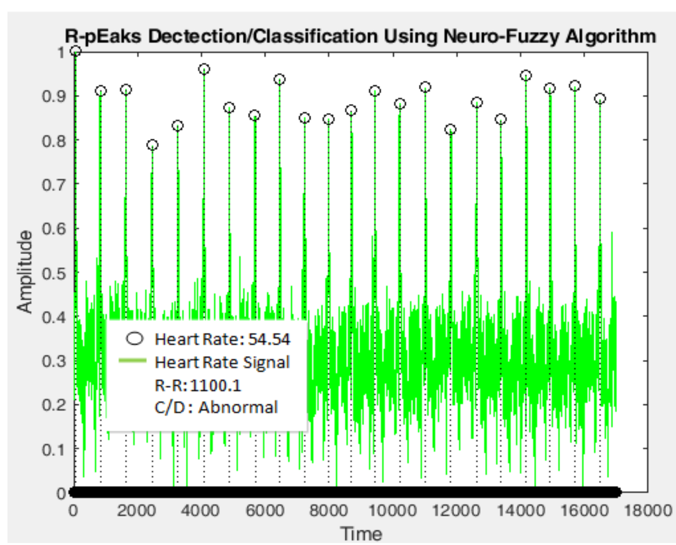

Figure 6: ECG R-R Peaks Detection for Sample 2

V. CONCLUSION

The paper proposed a digital signal model for ECG signal for visualizing abnormalities of the heart. The model is more efficient than other existing models because of the additional classification and recognition of the signal using filtered input data which is free from noise. The main significance of this model is that it can be used and understood by non-medical personnel as well.

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