Identification of Cardiac Ischemia Using Spectral Domain Analysis of Electrocardiogram

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***Abstract*— India has highest incidence of heart related diseases in the world. If no initiative is taken to check the disease the most predictable and preventable among all chronic diseases, India will have 62 million heart patients by 2015. Myocardial ischemia (also known as angina) is a heart condition caused by a temporary lack of oxygen-rich blood to the heart. Cardiac ischemia (CI) is a heart disease that covers heart issues caused by narrowing of the arteries which makes less oxygenated blood to reach the heart muscle. This may lead to heart attack with no prior warning. This paper introduces the work that has been done to distinguish the Electrocardiogram (ECG) of a normal healthy human from that of an ischemia patient. Fast Fourier Transform (FFT) on ECG Signal was used to extract information and providing the basis with which a signal suggesting predisposition of the patient who suffers from Cardiac ischemia. The main aim is to design algorithm that enable the doctors to diagnose cardiac ischemia on the basis of spectral analysis of an ECG signal. 4 min. of ECG of any patient is enough to detect possibility of ischemia.Normal Sinus Rhythm Data is obtained from MIT-BIH NSR Database. Ischemia data is obtained from European ST-T Database. The data is taken for duration of 1 hour. The algorithm was tested on MIT-BIH database and European ST-T Database and the verification of results using MATLAB is done. This concept can be utilized to analyze ECG signals to identify other heart diseases**

***Keywords*—ECG, FFT, ischemia, spectral analysis**

I. INTRODUCTION

Electrocardiography deals with the electrical activity of the heart. It is considered as a representative signal in cardiac physiology, useful in diagnosing cardiac disorders. The medical state of the heart is determined by the shape of the Electrocardiogram. During the action of pumping blood into body, heart generates ECG signal which contains important pointers to different types of diseases afflicting the heart. The biggest challenge faced by the models for automatic heart beat classification is the variability of the ECG waveforms from one patient to another even within same person. However, all the cardiac ischemia patients have certain common characteristics. Thus the objective is to identify those characteristics so that the diagnosis can be general and as reliable as possible.

Significant work has been done on time domain analysis of ECG, however the spectral domain analysis gives a different look into the signal and spectral parameters give a unique representation of signal that helps to understand the activity of the heart. Joseph Fourier stated that any periodic signal can be represented as sum of sinusoids, each representing a different frequency. ECG is a periodic signal, its spectrum must contain valuable data effect on time domain portion, every disease should have its effect on the spectrum of the ECG as well.

The above explained concept provided the motivation to perform this work in frequency domain to help enable physicians in future to identify diseases based not only on time domain analysis but spectral analysis as well. Furthermore, future aim is to identify diseases based on spectral domain that are not at all detected in time domain. ECG signal consists of 3 significant portions, P-wave, QRS complex and T-wave shown in figure 2. The P wave represents atrial depolarization, QRS complex represents ventricular depolarization and T wave represents ventricular recovery or re-polarization. It has been shown that significant information is present in QRS complex and QRS complex plays a significant role in heart diseases, so it was obvious that implementation of the algorithm, for a start, should be on QRS complexes.

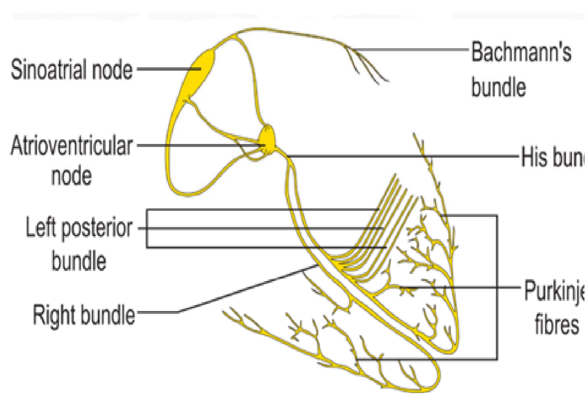

Figure .1 Electrical conduction system of heart

The ECG works by detecting and amplifying the tiny electrical changes on the skin that are caused when the heart muscle depolarizes during each heartbeat. At rest, each heart muscle cell has a charge across its outer wall, or cell membrane. Reducing this charge towards zero is called de-

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polarization, which activates the mechanisms in the cell that cause it to contract. During each heartbeat a healthy heart will have an orderly progression of a wave of depolarization that is triggered by the cells in the sinoatrial (SA) node, spreads out through the atrium, passes through "intrinsic conduction pathways" and then spreads all over the ventricles. This is detected as tiny rises and falls in the voltage between two electrodes placed either side of the heart which is displayed as a wavy line. This display indicates the overall rhythm of the heart and weaknesses in different parts of the heart muscle.

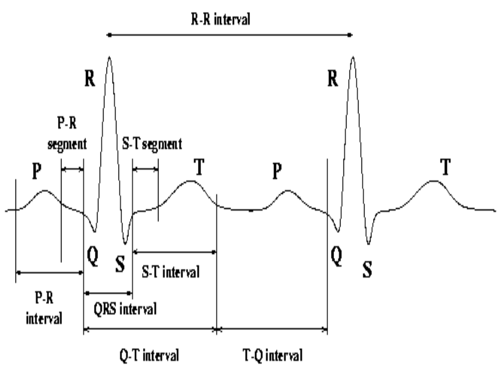

Figure. 2 Successive heart beats of the ECG signal

Cardiac ischemia is a heart disease that covers heart issues caused by narrowing of the arteries which makes less oxygenated blood to reach the heart muscle. When the coronary arteries cannot supply enough oxygen-rich blood to the heart, symptoms of myocardial ischemia can occur.This disease may lead to heart attack with no prior warning and without pain. Myocardial ischemia, also called cardiac ischemia, can damage heart muscle, reducing its ability to pump efficiently. Myocardial ischemia may also cause serious abnormal heart rhythms. These events are most often initiated with symptoms like Shortness of breath, persistent coughing or wheezing. Due to ischemia blood backs up in the pulmonary veins because the heart can't keep up with the supply. There are five preventable risk factors that will lead to coronary heart disease.

- Smoking
- Physical Inactivity
- High Blood Cholesterol
- High Blood Pressure
- Being Overweight

Treatment for myocardial ischemia is directed at improving blood flow to the heart muscle and may include medications, a procedure to open blocked arteries or coronary artery is bypass surgery. There are three types of myocardial ischemia: stable, unstable, variant. Unstable myocardial ischemia is a dangerous condition that requires emergency treatment. It is a sign that a heart attack could occur soon. Unlike stable myocardial ischemia, it does not follow a pattern. It can occur without physical exertion and is not relieved by rest or medicine. Myocardial ischemia is not a heart attack, but it does mean that there is a greater chance of having a heart attack. The pain associated with myocardial ischemia means that some of the heart muscle temporarily is not getting enough blood. A heart attack, on the other hand, occurs when the blood flow to a part of the heart is suddenly and permanently cut off, usually by a blood clot. This can lead to serious heart damage.

The aim of the paper is to analyze and compare normal person ECG with a patient ECG who prone to cardiac ischemia. The Normal Person ECG Data is obtained from MIT-BIH NSR Database and Ischemia data is obtained from European ST-T Database. A change in activity of heart means that the significant spectrum of the signal should be affected as well. By calculating the Fast Fourier Transform and threshold the signal for the significant lobe of spectrum, different parameters that the signal represented were calculated. Frequency domain segmentation was done and energy is computed in each domain. The parameters were also plotted using two dimensional plots to show significant difference in the desired and pathological parameters.

II THE FAST FOURIER TRANSFORM

A. The Fast Fourier Transform

Discrete Fourier Transform, (DFT), is a special kind of discrete transform that converts the time domain signal into frequency domain. The input to the DFT is a finite sequence of real or complex numbers making the DFT ideal for processing information stored in computers. In particular, the DFT is widely employed in signal processing and related fields to analyze the frequencies contained in a sampled signal. A DFT decomposes a sequence of values into components of different frequencies. This operation is useful in many fields but computing it directly from the definition is often too slow to be practical. Fast Fourier Transform, (FFT) [5] is a way to compute the same result more quickly. The difference in speed can be substantial, especially for long data sets where N may be in the thousands or millions in practice, the computation time can be reduced by several orders of magnitude in such cases, and the improvement is roughly proportional to $N/\log(N)$. This huge improvement made many DFT-based algorithms practical; FFTs are of great importance to a wide variety of applications in digital signal processing.

Fast Fourier Transform technique (RADIX 2 FFT) is applied to distinguish Ischemia person from Normal person. Normal Person ECG, i.e., Normal Sinus Rhythm Data is obtained from MIT-BIH NSR Database. ECG signal is obtained in the form of samples, sampled at the rate of 128 Hz. Ischemia data is obtained from European ST-T Database. ECG signal is in the form of samples, sampled at the rate of 250 Hz. Both the data is taken for duration of 1 hour. No. of samples of NSR Data:4,60,800, No. of samples of Ischemia Data: 9, 00,000.About 40 Normal and 40 Ischemia subjects' data are analyzed. Mean is removed from both the data, so that DC Level can be removed. Data is filtered to remove power line interference. The filtered data is converted into frequency domain using 2048 point Radix-2 FFT.The obtained frequency samples are divided into five regions:

R1: 0-2 Hz
R2: 2-8 Hz
R3: 8-16 Hz
R4: 16-22 Hz
R5: 22-32 Hz

Energy is computed in every regions and is normalized.

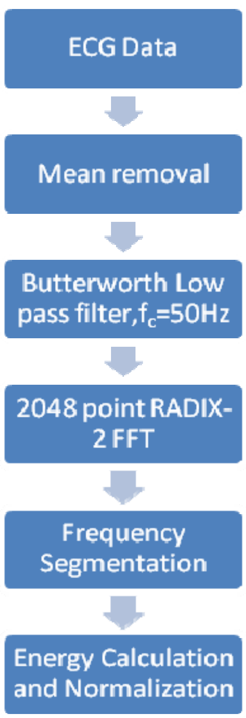

Figure.3 Flow chart showing FFT Method of Execution

III STATISTICAL PARAMETERS

The following Statistical parameters are computed:
Mean: It is the average of the samples in the respective frequency segment. It is calculated as

$$Mean = \sum_{k=0}^{n} f(k)$$

Where f (k) is the amplitude level of the k^{th} sample in the frequency segment

Median: It is the numerical value separating the higher half of the samples from the lower half.

Standard deviation: Standard deviation is a widely used measure of variability used in statistics and probability theory. It shows how much variation exists from the mean. A low standard deviation indicates that the data points tend to be very close to the mean, whereas high standard deviation indicates that the data points are spread out over a large range of values.The way to calculate it is to compute the squares of the distance from each data point to the mean of the set, add them all up, divide by n-1 and take the positive square root. It shows how much variation exists from the mean value.

$$SD = \sqrt{E(X - mean)^2}$$

Energy: It is computed as follows

$$Energy = \sum_{k=0}^{n} f(k)^2 \qquad (3)$$

IV RESULTS AND DISCUSSIONS

Comparison of energy levels in various regions

Table I. Various parameter comparison: CI e0122 vs NSR 16265

	STT			
	mean	median	standard deviation	energy
R1	0.043989751	0.024636471	0.049578939	0.142516519
R2	0.040477897	0.02962224	0.035225475	0.283809295
R3	0.019747531	0.016411544	0.012414012	0.071119413
R4	0.005325102	0.004339976	0.003575095	0.004018744
R5	0.001137529	0.000860414	0.000949271	0.000214217
	NSR			
	mean	median	standard deviation	energy
R1	0.018663639	0.009436764	0.028541829	0.037563288
R2	0.031376278	0.016164613	0.036561148	0.228460935
R3	0.032198404	0.025882435	0.022025213	0.198876873
R4	0.015916628	0.015162552	0.009095033	0.032851032
R5	0.003531018	0.002562219	0.003101157	0.002154738

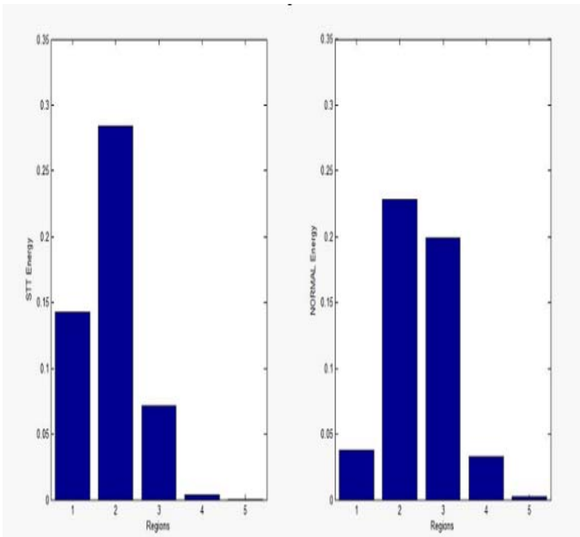

Figure.4 Energy Comparison: CI e0122 vs NSR 16265

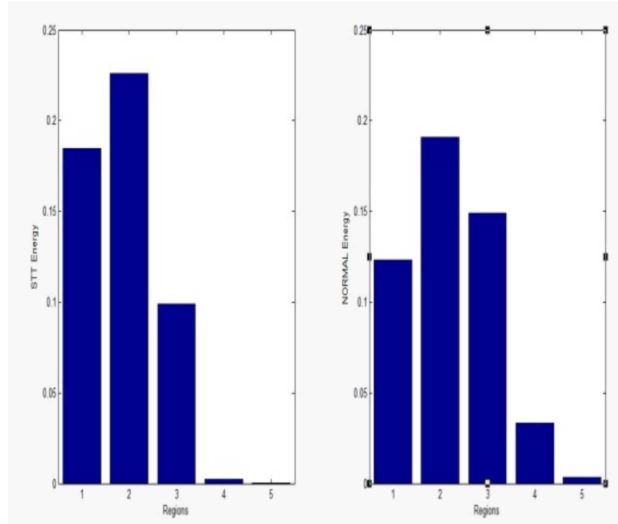

Figure. 5 Energy Comparison: CI e0114 vs NSR 16795

Table II . Various parameter comparison: CI e0114 vs NSR 16795

		STT		
	mean	median	standard deviation	energy
R1	0.062477886	0.051759114	0.04184236	0.184840102
R2	0.041474624	0.039187612	0.023802804	0.2258185
R3	0.022799902	0.019164297	0.015444722	0.099108582
R4	0.003801539	0.002983294	0.002701863	0.002124373
R5	0.000809001	0.000492449	0.00065583	0.00010586
		NSR		
	mean	median	standard deviation	energy
R1	0.042272112	0.027674334	0.044844319	0.123321151
R2	0.03020436	0.022797809	0.032058209	0.191035451
R3	0.029424808	0.026005818	0.016599224	0.14924178
R4	0.015268692	0.013040146	0.010352354	0.033242638
R5	0.004756805	0.004251501	0.00319341	0.003206658

Table III. Various parameter comparison: CI e0103 vs NSR 17502

		STT		
	mean	median	standard deviation	energy
R1	0.070062249	0.063623819	0.052727919	0.250955186
R2	0.040845857	0.037816443	0.025505723	0.228923126
R3	0.009997297	0.007248202	0.008132581	0.021690973
R4	0.003429989	0.002929688	0.002450968	0.001735655
R5	0.001139344	0.000983835	0.000625338	0.000165146
		NSR		
	mean	median	standard deviation	energy
R1	0.026090606	0.016048914	0.025907598	0.043942267
R2	0.03758352	0.035036274	0.02732711	0.213023128
R3	0.032889344	0.031062309	0.018963739	0.188454915
R4	0.019468293	0.01715798	0.011217483	0.049349111
R5	0.006309719	0.005519224	0.004007518	0.005459469

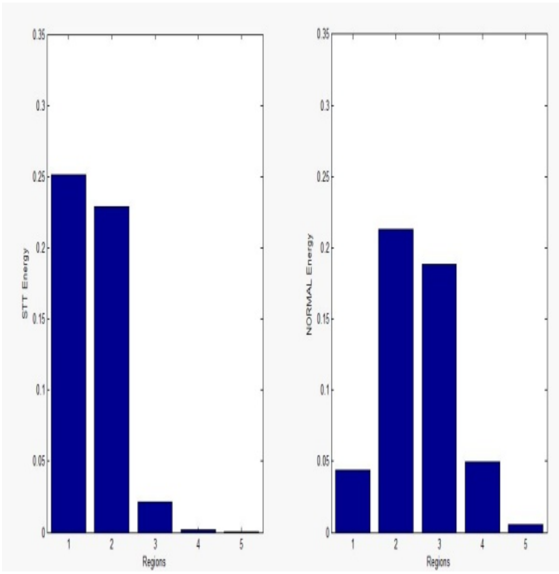

Figure. 6 Energy Comparison: CI e0103 vs NSR 17502

V CONCLUSION

Fast Fourier Transform has given satisfactory results shown in figures. The most significant feature that differentiates a normal person and Ischemia patient is found to be the energy levels at different frequencies. So, Ischemia patient can be identified by finding his ECG energy levels and comparing them with that of a normal person ECG. This method can be used to identify other heart disorders.

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