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HIGHER ORDER SPECTRAL ANALYSIS TO IDENTIFY CARDIAC ARRHYTHMIAS

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ABSTRACT

In the modern industrialized countries every year millions of people die due to cardiac disorders. India has highest incidence of heart related diseases in the world. According to W.H.O. statistics, if no initiative is taken to check this most predictable and preventable among all chronic diseases, world will have to suffer with millions heart patients. Atrial Fibrillation (AF), Cardiac Ischemia (CI) and Sudden Cardiac Arrest (SCA) are most common types of cardiac arrhythmias. Processing of cardiac signal and identifying the cardiac disorders is challenging task in bio medical engineering. This paper introduces the work that has been done to distinguish the Electrocardiogram (ECG) of a normal healthy human(Normal Sinus Rhythm-NSR) from that of the patients affected by AF,CI,SCA. The aim of this paper is to identify cardiac arrhythmia using non linear signal processing technique such as higher order spectral analysis. Normal Spectral analysis of ECG provides only the power within frequency components but doesn't give any phase relations. So higher order spectral analysis is used to find Bispectrum, Bicoherence and Quadratic Phase Coupling to detect and characterize phase coupled harmonics in ECG. The plots of bi-spectrum and bi-coherence are potential visual aids presented in the report to analyze the cardiac problems. The experimental results indicate that Higher Order Spectral Analysis produce the best performance compared to normal spectral analysis. ECG data is collected from MIT-BIH Database. The verification of results is done by using MATLAB tool box.

KEYWORDS: Electrocardiogram (ECG), Normal Sinus Rhythm (NSR), Atrial Fibrillation (AF), Cardiac Ischemia (CI) and Sudden Cardiac Arrest (SCA)

INTRODUCTION

The Electrocardiogram (ECG] is an important bio-medical signal representing the electrical activity of the heart. With manual ECG signal analysis, identifying and diagnosing the cardiac disease is a challenging task to the cardiologist. So computer based analysis is required to diagnosis the Cardiac diseases.

The state of cardiac heart is generally reflected in the shape of ECG waveform and heart rate. ECG can be properly analyzed and it can provide information regarding various diseases related to heart. Various contributions have been made in literature regarding beat detection and classification of ECG signals. Most of them use either time or frequency domain representation of the ECG waveforms. The most difficult problem faced by today's automatic ECG analysis is the large variation in the morphologies of ECG waveforms. Lot of Research work has been done in the past to identify cardiac arrhythmias in time domain analysis and in frequency domain analysis. Basic objective is to come up with a simple method having less computational time without compromising with the efficiency. In this paper, identification of cardiac disorder is implemented using higher order spectral analysis.

Normal spectral analysis is a good tool for the analysis of power distribution of stationary process. It is not an appropriate tool for the analysis of non stationary signals such as ECG. These processes are based on the linearity of the system. It is phase blind and hence, it doesn't contain any information about the phase of the signal. Phase correlations are possible in ECG signal. Phase correlations among rhythmic events at different frequencies are introduced only by non-linear interactions. Thus non-linear analysis methods have to be applied for the detection of non-linear correlations. One such method for the study of such non-linear effects is to quantify the deviation of the measured ECG signal from gaussianity by utilizing the bispectrum. This approach often detects important quadratic phase correlations present among the other higher order correlations. This concept has provided the motivation to perform this work in Bispectral analysis of ECG signal to enable the physicians to identify heart diseases. Nonlinear signals like ECG, being a quasi- periodic, non-stationary and mixed phase signal, exhibits phase coupling between the frequency components of the signal. Motivation behind using higher order spectra (HOS) is its ability to suppress Gaussian noise and to preserve the true phase characteristics of a non-minimum phase signal, from which signal reconstruction is possible

BLOCK DIAGRAM REPRESENTATION OF THE PROCESS

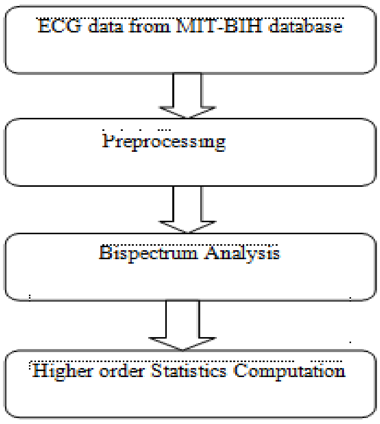

Figure 1

In the frequency domain the second-order measure is called the power spectrum P (k) and it can be calculated in two ways:

Take a Discrete Fourier Transform (DFT) of the autocorrelation function:

P (k) = DFT[R (m)]

(Or)

Multiply together the signal Fourier Transform X (k) with its complex conjugate: P (k) = X (k) X*(k)

Third-order Bispectrum B (k, l) can be calculated in a similar way:

Take a Double Discrete Fourier Transform (DDFT) of the third-order cumulant:

B (k, l) = DDFT [C_3]

Where 'C_3' is third order cumulant.

(Or)

Form a product of Fourier Transforms at different frequencies:

B(k,l) = X(k) X(l) X*(k+l)

QUADRATIC PHASE COUPLING

Bispectral analysis is a powerful tool to detect QPC and has been applied successfully to evaluate. An important class of nonlinear interaction, named quadratic phase coupling (QPC) involves frequency triplet f1, f2 and f1+f2.

QPC means that the sum of the phases at f1 (φ1) and f2 (φ2) is the phase at frequency f1+f2 (i.e.φ1+ φ2) which is often an indication of second – order nonlinearities. QPC occurs when two waves interact non-linearly and generate a third wave with a frequency equal to the sum/difference of the first two waves.

HOSA is capable of detecting and characterizing quadratic phase coupling.

Table 1

f1, f2, 2f1	$\Phi_1, \Phi_2, 2\Phi_1$
f1, f2, f1+f2	$\Phi_1, \Phi_2, \Phi_1+\Phi_2$
f1, f2, f1-f2	$\Phi_1, \Phi_2, \Phi_1-\Phi_2$

BISPECTRUM

Bispectrum of a signal is defined as the second order Fourier transform of the third order cumulants of a signal. It is given by

$$S_3^x(\omega_1,\omega_2) = \sum_{\tau_1=-\infty}^{\infty}\sum_{\tau_2=-\infty}^{\infty} c_2^x(\tau_1,\tau_2)\exp[-j(\omega_1\tau_1+\omega_2\tau_2)]$$

The bispectrum is a function of two-frequency variables f1 and f2. The bispectrum analyses the frequency components at f1, f2, (f1+f2) or (f1-f2).

BICOHERENCE

It is the squared-magnitude of the normalized bispectrum.

$$B_{norm}(f_1,f_2) = \frac{E[X(f_1)X(f_2)X^*(f_1+f_2)]}{\sqrt{P(f_1)P(f_2)P(f_1+f_2)}}$$

Measure quantifying the extent of phase coupling in a signal.

HIGHER ORDER SPECTRAL PARAMETERS

Variance: It is a measure of the spread of the data from the mean.

Skewness: It is a measure of asymmetry of data around the sample mean

Kurtosis: It is a measure an extreme deviation from mean the distribution is

Table 2

ECG Data	SKEWNESS	KURTOSIS	VARIANCE
NSR	0.399	4.0401	2498.59
CI	0.8450	15.289	615.18
SCA	0.9274	6.0340	1111.4
AF	0.9465	9.0218	750.88

RESULTS

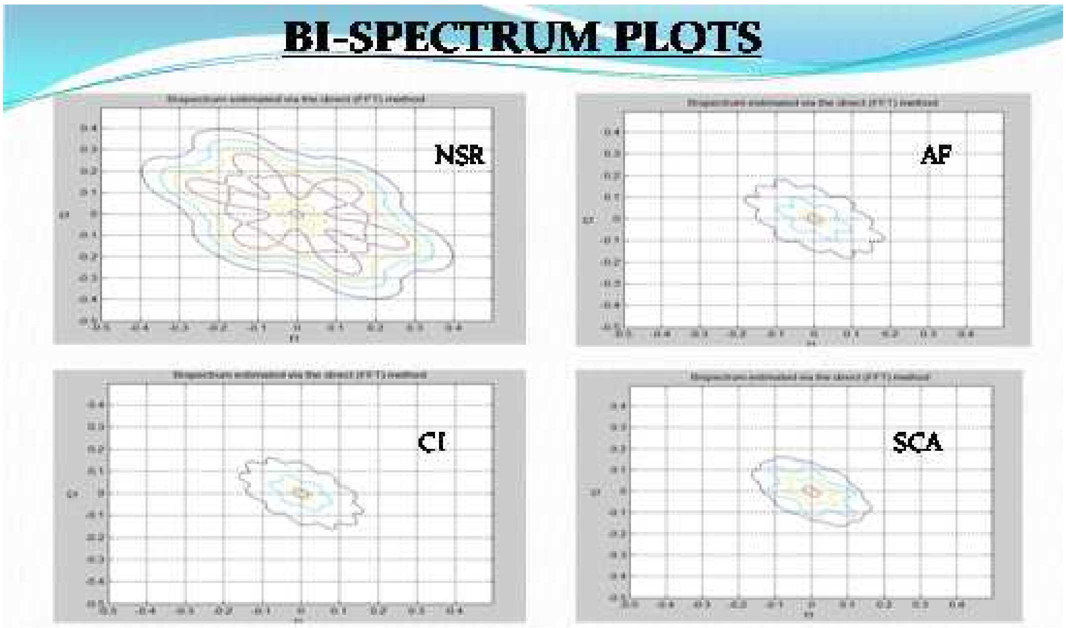

Figure 2

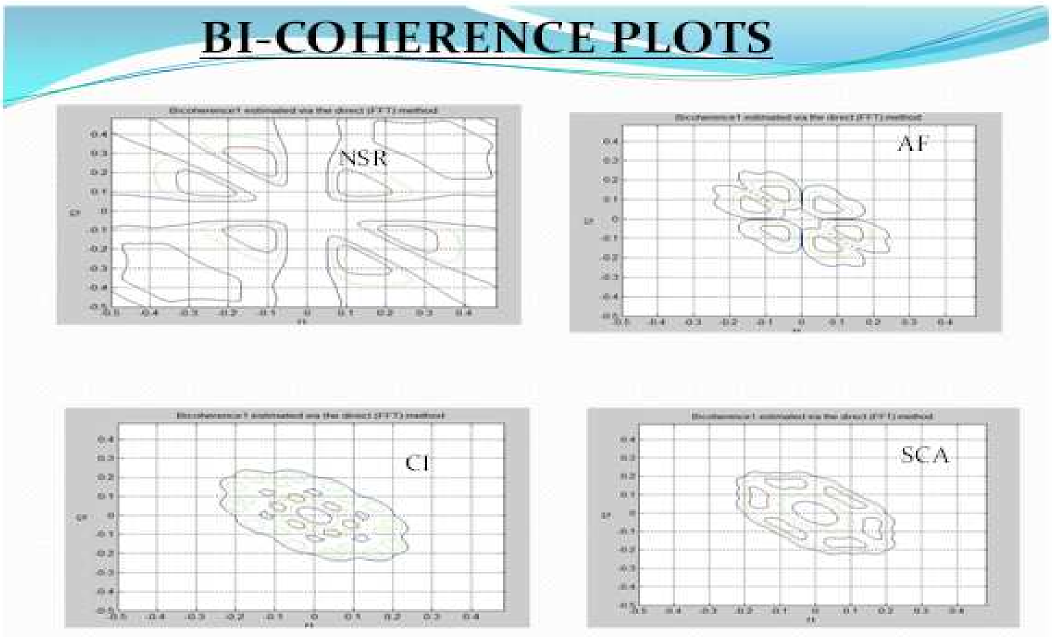

Figure 3

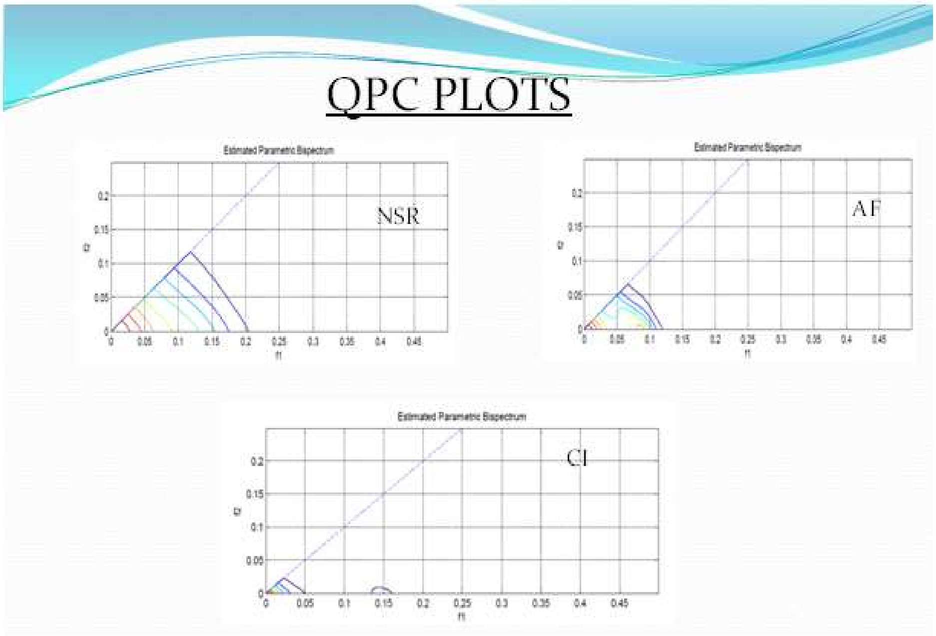

Figure 4

CONCLUSIONS

- The plots of bi-spectrum and bi-coherence are potential visual aids presented in the report to analyze the cardiac problems.
- About 15 Normal, 15 Sudden Cardiac Arrest, 23 Cardiac Ischemia and 16 Atrial Fibrillation person's ECG data were analyzed.
- The Bispectrum and Bicoherence plots are useful for visual interpretation by differentiating NSR person with diseased person. Further this method can be used to identify other heart disorders**.**

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