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Coherence among Electrocardiogram and Electroencephalogram Signals as Non- Invasive Tool of Diagnosis

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Abstract-Degree of association or coupling of frequency spectra between the ECG (electrocardiogram) and EEG (electroencephalogram) signals at a particular frequency is presented in this paper. Degree of association or coupling of frequency spectra between two signals is called Coherence.ECG orelectrocardiogram and EEG or electroencephalogram are very important parameters when it comes to diagnosis and treatment of human heart and brain related problems. For this reason signal processing of such signals are most important. A continuous non-invasive, low cost and accurate monitoring of functioning of heart and brain have been proven to be invaluable in various diagnostics and clinical applications. In this paper coherence between simultaneously taken ECG signals and EEG signals of four different subjects is presented.The EEG signals acquired from the four different positions; the Frontal($F_{p_1} - F_{p_2}$), Central($C_3 - C_4$), Parietal($P_3 - P_4$) and Occipital ($O_1 - O_2$) Brain Regions. Coherence is analysed by obtaining magnitude squared coherence parameters at a certain frequency band (Very Low, Low and High) using Welch method of Power Spectrum Estimation.

***Keywords*—** Auto-Power Spectral Density, Magnitude Squared Coherence (MSC), Welch Method, ECG, EEG, Coherence, Parietal, Occipital, Frontal, Cerebellum.

1. Introduction-

An electrocardiogram or ECG is today used worldwide as a relatively simple tool of diagnosis of conditions of heart. An ECG is a recording of the small electric waves being generated during heartbeat. There are specialized cells producing electricity, are called natural pacemaker cells. These cells produce electricity by quickly changing their electrical charge from positive to negative and again from negative to positive. The first electric wave in a heartbeat is initiated by sinoatrial node placed at top of heart. Heart muscle cells have ability to spread its electric charge to adjacent heart muscle cells and this initial wave will be enough to start a chain reaction. An electroencephalogram or EEG Signal reflects the electrical activity of human brain. Neurons or nerve cells transmit information throughout the body electrically and they create electrical impulses by the diffusion of sodium, calcium, and potassium ions across the cell membranes. When a person is thinking, watching television or reading, different parts of the brain are stimulated. It creates different electrical signals that can be monitored by an EEG .There are five major brain waves distinguished by their different frequency ranges and amplitudes. These frequency bands from low to high frequencies respectively are called alpha (α), theta (θ), beta (β), delta (δ), and gamma (γ). These frequency bands are seen in different states of mind.

Coherence is the degree of association of frequency spectra between the ECG and EEG signals at a particular frequency. The magnitude squared coherence (MSC) estimate between two signals x (ECG Signal) and y (EEG Signal) is given below:

$$C_{xx}(f) = \frac{|P_{xy}(f)|^2}{P_{xx}(f) \times P_{yy}(f)} \quad (1)$$

Here $C_{xx}(f)$ is magnitude squared coherence estimate between two signals x (ECG signal) and y (EEG signal).

If MSC between two signals is positive its mean changing nature of that two signals are same. If MSC of two signals is negative its mean changing nature of that two signals is opposite. MSC zero mean there is no relationship between two signals. Coherence phase is given as

$$\theta_{(f)} = \tan^{-1}\left\{\frac{\mathrm{Im}\{P_{xy}(f)\}}{\mathrm{Re}\{P_{xy}(f)\}}\right\} \quad (2)$$

Where $P_{xx}(f)$ is the power spectral estimation of x (ECG) signal and $P_{yy}(f)$ is the power spectral estimation of y (EEG) signals. $P_{xy}(f)$ is the cross power spectral estimation of the ECG and EEG signals. Estimation of coherence amongPhysiological signals is used as low cost and accurate non-invasive tool of diagnosis of brain. [1-5]. In this research work ECG and EEG signals are acquired from four different patients. Length of these signals is five second. These signals are sampled at 1000 sample per second. Coherence between ECG and EEG is analysed by using Welch method. Main objective of this work is to find the region of brain which has

maximum association with brain. Coherence among ECG and EEG is used for differentiating between normal and abnormal brain activity. It is used as cost effective tool of non-invasive diagnosis.

2. Method-

Technique used in this research work is based on classical Welch method of power spectrum estimation. Which utilizes the 50% overlap of data segment along with the use of hamming window. [6,7]
Using Welch method power spectral density (PSD) of ECG signal and EEG signal is given below
PSD of x (ECG Signal):

$$P_{xx}(f) = \frac{X(f)X^*(f)}{NT} \quad (3)$$

PSD of y (EEG Signal):

$$P_{yy}(f) = \frac{Y(f)Y^*(f)}{NT} \quad (4)$$

Cross power spectral density (CPSD) of x and y:

$$P_{xy}(f) = \frac{X(f)Y^*(f)}{NT} \quad (5)$$

Or,

$$P_{xy}(f) = \frac{Y(f)X^*(f)}{NT} \quad (6)$$

MATLAB is utilised for the implementation of Welch method. Windowing technique used in Welch method is changed and on the place of default hamming window Kaiser Window is utilised. In Welch method signals are divided into K segments. Over lapping of segments is kept 50%. For our research work 1024 point FFT is used. [8,9]

3. Analysis and Results-

Coherence between the ECG and corresponding EEG signals acquired from the four prominent brain regions named as the Central($C_3 - C_4$), Frontal($F_{p_1} - F_{p_2}$), Occipital ($O_1 - O_2$) and Parietal ($P_3 - P_4$)is investigated. All data are collected from healthy subjects under the age group (21-36 years old) at the sampling rate is 1000samples/second.

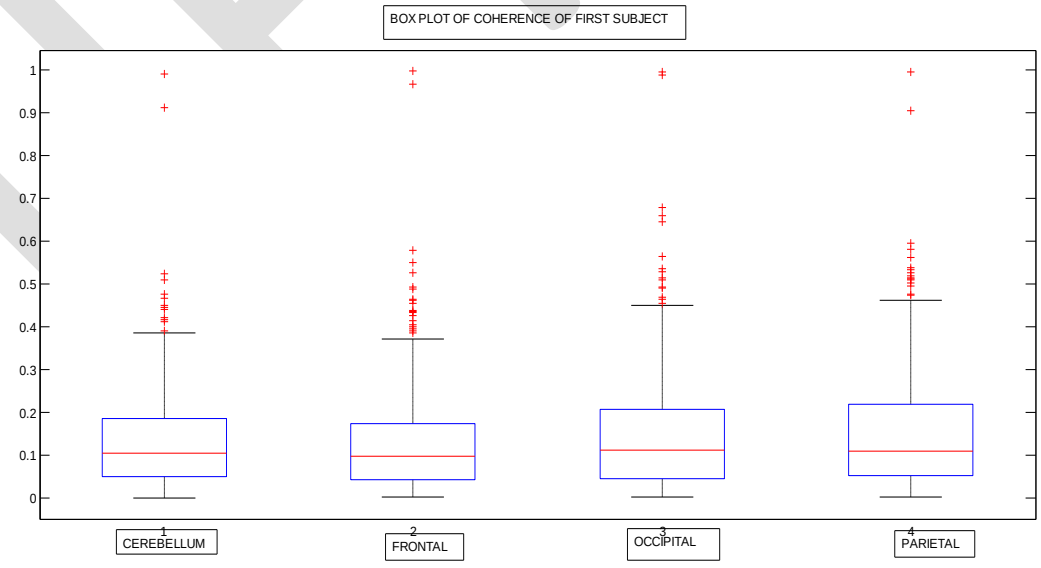

Figure.1 Box plot of MSC of first subject.

From figure.1 Maximum mean of Magnitude squared coherence 0.1501 is at cerebellum. No of coherence points greater than 0.5 at cerebellum, frontal, occipital and parietal are respectively 14, 15, 11 and 13.

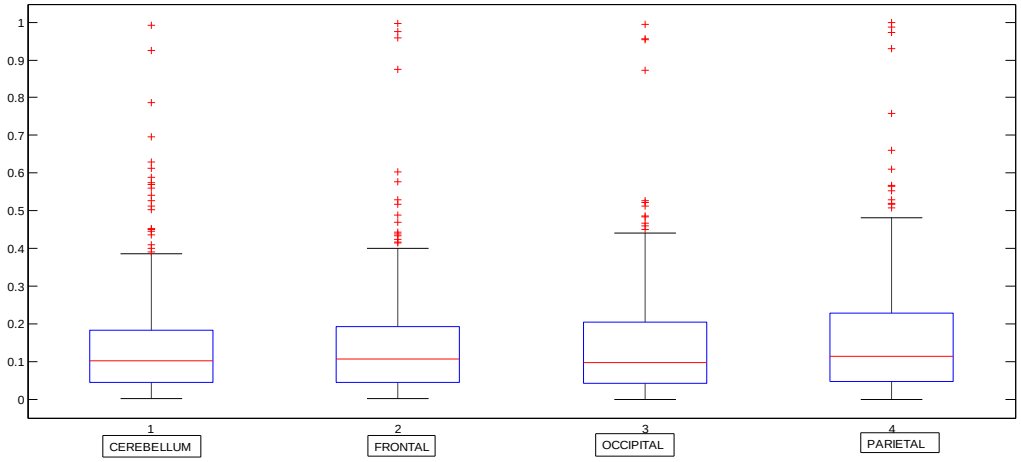

Figure.2 Box plot of MSC of second subject.

From figure.2 Maximum mean of Magnitude squared coherence 0.1691 at cerebellum. No of coherence points greater than 0.5 at cerebellum, frontal, occipital and parietal are respectively 14, 8, 14 and 14.

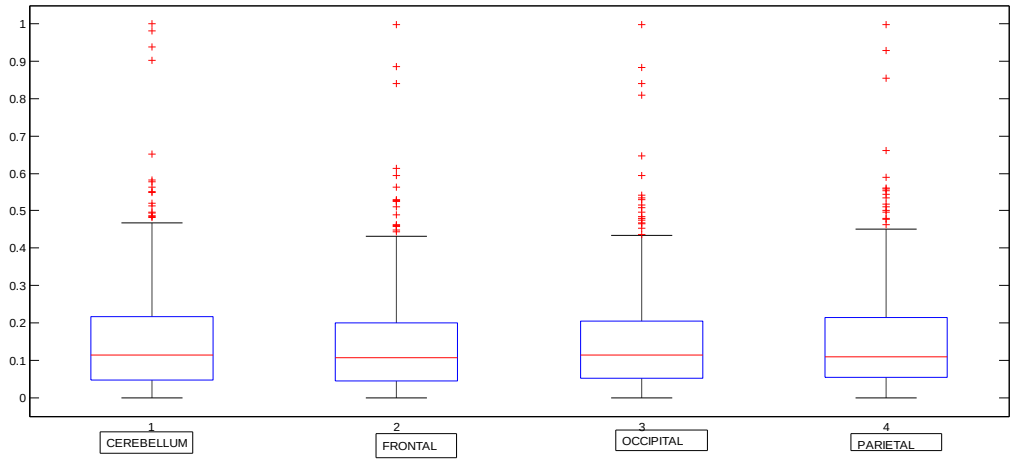

Figure.3 Box plot of MSC of third subject.

From figure.3 Maximum mean of Magnitude squared coherence 0.1510 is at cerebellum. No of coherence points greater than 0.5 at cerebellum, frontal, occipital and parietal are respectively 12, 10, 16 and 15.

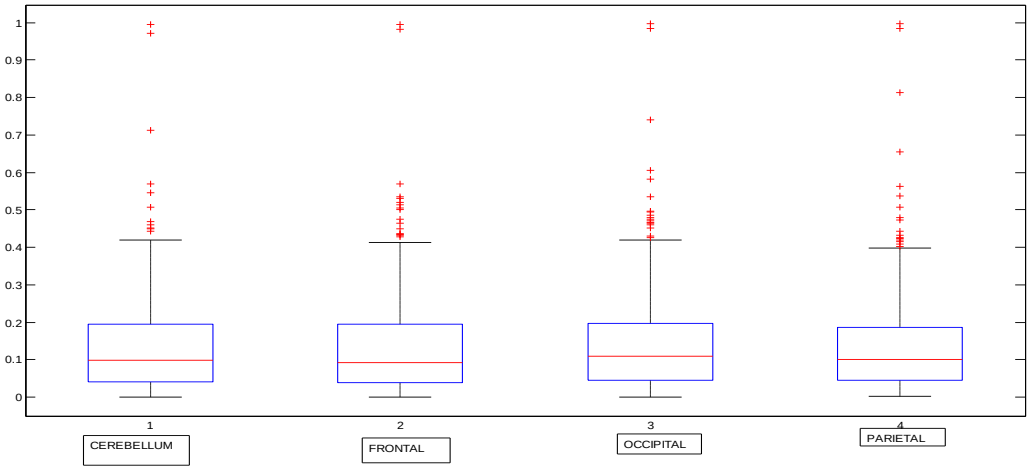

Figure.4 Box plot of MSC of fourth subject.

From figure.4 Maximum mean of Magnitude squared coherence 0.1413 is at parietal. No of coherence points greater than 0.5 at cerebellum, frontal, occipital and parietal are respectively 6, 7, 9 and 7.

Table.1 Final Estimated Result

	Mean of coherence				Coherence points greater than 0.5			
	Cerebellum	Frontal	Occipital	Parietal	Cerebellum	Frontal	Occipital	Parietal
1st Subject	0.1326	0.1266	0.1484	0.1501	4	5	11	13
2nd subject	0.1394	0.1446	0.1474	0.1578	9	8	8	19
3rd subject	0.1510	0.1433	0.1491	0.1542	12	10	12	15
4th subject	0.1351	0.1332	0.1413	0.1359	6	9	6	7

From the table.1 it is clear that maximum coherence > 0.5 is at Parietal for first three subjects and also mean of coherence is maximum for first three subjects at parietal. Mean of Coherence at frontal is minimum for three different subjects. For first subject maximum mean of coherence is .1501 at parietal and minimum mean of coherence is 0.1266 at frontal. For second subject maximum mean of coherence is 0.1578 at Parietal and minimum mean of coherence is 0.1394 at cerebellum. For third subject maximum mean of coherence is 0.1542 at parietal and minimum mean of coherence is 0.1433 at frontal. For fourth subject maximum mean of coherence is 0.1413 at occipital and minimum mean of coherence is 0.1332 at frontal.

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5. Conclusion application and future scope-

ECG and EEG signals are completely coherent if the magnitude squared coherence is equal to 1 and if MSC is equal to zero then two signals are independent to each other. In this research work MSC is non zero between ECG and EEG signals for all four subjects, its mean there is association between ECG and EEG signals. It may possible to acquire the EEG signal information from the ECG signal by PSD estimation using welch method. Estimation of coherence among Physiological signals are used as a tool for analysis of association between two Physiological organs. Coherence among different ECG and EEG signals is help full in finding the difference between normal and abnormal mental activity. It is also helpful in finding the defective brain region. Brain region where is large deviation in mean of coherence from standard mean of coherence is termed as defective region. After investigating the defective brain region we can diagnosis and supply drugs to that particular brain region rather than whole brain. It is used as non-invasive tool of diagnosis. Mean of coherence of N (N any large no.) subjects is used as standard mean. Any deviation from this standard is identify as abnormality. It is a cost effective and accurate tool of non-invasive diagnosis.

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