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Effect of Congestive Heart Failure in Statistical Nature of Electrocardiogram Signal

Santanu Chattopadhyay[1], Gautam Sarkar[2], Arabinda Das[3]

Jadavpur University, Kolkata, India ([1]sansur12ct@yahoo.com, [2]sgautam63@gmail.com, [3]adas_ee_ju@yahoo.com)

Abstract

Sometimes heart pumps inaccurately and inefficiently due to gradual accumulation of fluid surrounding the heart. It is commonly referred as Congestive Heart Failure (CHF). Among different types of heart diseases CHF is severe one which may sometimes lead to the death of the patient. Various attempts have been taken for early detection of CHF. Study of CHF has been made in this paper by estimation of statistical parameter obtained from electrocardiogram (ECG) signal. Wavelet decomposition is performed on ECG signal by applying Discrete Wavelet Transformation (DWT). Wavelet coefficients are determined and there skewness has been determined both for normal person and CHF patient. Comparative study has been made which gives some distinct difference in skewness values with respect to DWT levels, radars and histograms which may be useful for early detection of CHF.

Key words

Congestive heart failure, Electrocardiogram, wavelet decomposition, statistical parameters

1. Introduction

Nature of electrocardiogram signals may vary due to different types of heart diseases. Congestive heart failure (CHF) is one of them that refers to inaccurate pumping due to accumulation of fluid surrounding the heart. A lot of research work has been going on to study congestive heart disease along with other heart diseases [1] – [3]. From a single ECG lead, an autoregressive model has been introduced for diagnosis of heart disease [1] – [3]. Different Heart Diseases have been classified by introducing a rough set decision system for Classification [2]. Different approaches for heart disease classification have been presented in [4]. [5] Dual tree complex wavelet transform has been applied on ECG signal for diagnosis of heart disease and spectral features have been extracted [5]. Along with fast Fourier Transform (FFT), wavelet based mathematical tools have been applied in biomedical application [6]-[9], prosthesis [6] and diagnosis of different hear diseases [7]-[10]. Force sensors have been used to capture foot pressure signals and have been used for walking pattern recognition using wavelet based tools [6]. Statistical parameters have been determined for diagnosis of heart diseases. In some recent work DWT based statistical parameters have been found in characterization for non-stationary signals and diagnosis of various diseases [9]-[10].

In some recent work, authors have utilized wavelet based statistical parameters in diagnosis of heart disease [11]-[12]. However, very few works have been found which apply DWT based statistical parameter for CHF diagnosis. This has motivated authors to classify ECG signals based on DWT based statistical parameter to extract specific features for diagnosis of CHF. In [12], discrete wavelet transformation has been carried out on electrocardiogram signals and skewness of approximate coefficients has been determined for diagnosis of congestive heart failure. The work has been extended here and skewness of detail coefficients has also been determined both for normal person and patient suffering from congestive heart failure. Comparative study has been made by using radars of those parameters and histogram.

2. DATA Collection:

Electrocardiogram signals have been taken from well-known data base of www.physionet.com. Signals have then been de-noised by passing them through numerical filter. Signals for normal person and patients suffering from congestive heart failure have been used for farther analysis.

3. Discrete Wavelet Transformation of ECG Signals

As electrocardiogram signal is non-stationary in nature wavelet analysis has been followed. Discrete wavelet transformation has been done on electrocardiogram signals up to DWT level 9, using ‘db4’ mother wavelets. At each DWT level both approximate and detail coefficients have been measured. As the data size of (approximate and detail) coefficients is large, it becomes difficult to deal with large number of data directly. For this reason, statistical behavior of these coefficients has been analyzed by their Skewness values. Steps for analysis have been presented as follows:

- Collect electrocardiogram signals
- Perform wavelet decomposition
- Determine approximate and detail coefficients
- Determine Skewness of coefficients
- Observe the change noticed due to Congestive Heart Failure

Results and observation in the change of statistical parameters have been discussed in following sub-section.

4. Skewness of Approximate Coefficients

Approximate coefficients have been determined at each DWT level of 1 to 9 for electrocardiogram signal collected from normal person as well as patients suffering from Congestive Heart Failure (CHF). For each level Skewness of Approximate Coefficients (SA) has been determined. SA values obtained for normal person and CHF patient have been presented in Table 1. To show the changes of SA of CHF with respect to SA of normal person, the ratio of these values have been calculated at each level. At i^{th} DWT level, the ratio for change of SA can be written as follows:

$$R_{SA_i} = \frac{SA_{CHF_i}}{SA_{N_i}} \quad (1)$$

With the help of SA_{CHF_i} and SA_{N_i} , the ratio R_{SA_i} corresponding to change of skewness of approximate coefficient in i^{th} DWT level has been calculated and present in Table 1.

SA values for normal person and CHF patient of Table 1 have been plotted in bar chart as shown in Fig. 1. It shows that SA for CHF patient is higher and almost constant from DWT level 1 to DWT level 3. Then their magnitudes are gradually decreasing. At DWT level 9, magnitude of SA of normal person is greater than that of CHF patient but in opposite direction.

Table 1

Skewness of approximate coefficients

DWT Level	SA (Normal) SA_{N_i}	SA (CHF patient) SA_{CHF_i}	$R_{SA_i} = \frac{SA_{CHF_i}}{SA_{N_i}}$
1	0.85	2.09	2.46
2	0.85	2.08	2.45
3	0.85	2.07	2.44
4	1.41	1.81	1.28
5	1.00	1.11	1.11
6	0.27	0.20	0.74
7	0.36	-0.17	-0.47
8	-0.07	0.15	-2.14
9	-0.76	0.08	-0.15

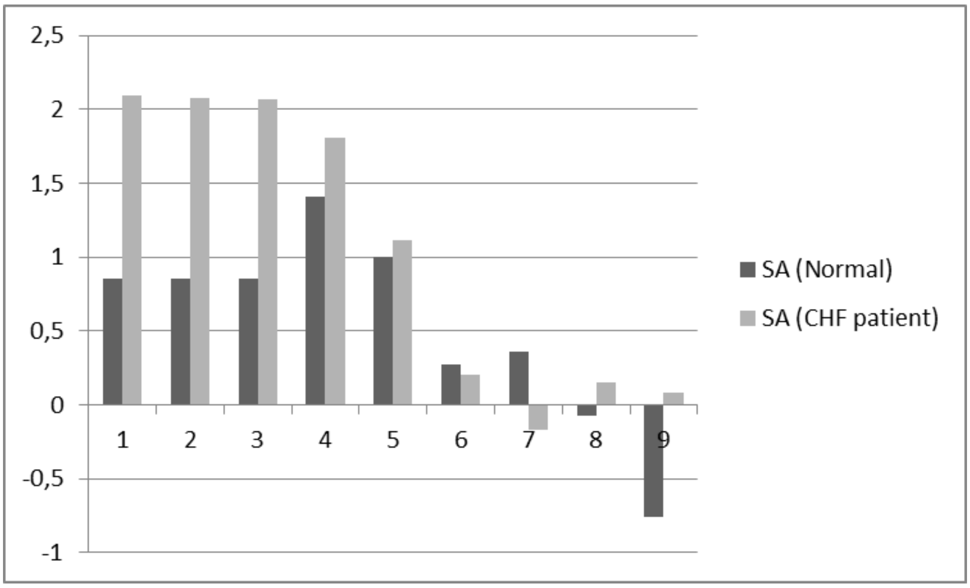


Fig. 1 SA of normal person and CHF patients

The ratio for change of SA due to congestive heart failure has been shown in Fig. 2. It shows that R_{SA_i} is constant up to DWT level 3 and then decreases. It becomes minimum and negative. Thus from this figure it may be concluded that may be possibility of CHF if

$$R_{SA_1} = R_{SA_2} = R_{SA_3} = constant > +2 \text{ and } R_{SA_8} = negative\ and\ < -2$$

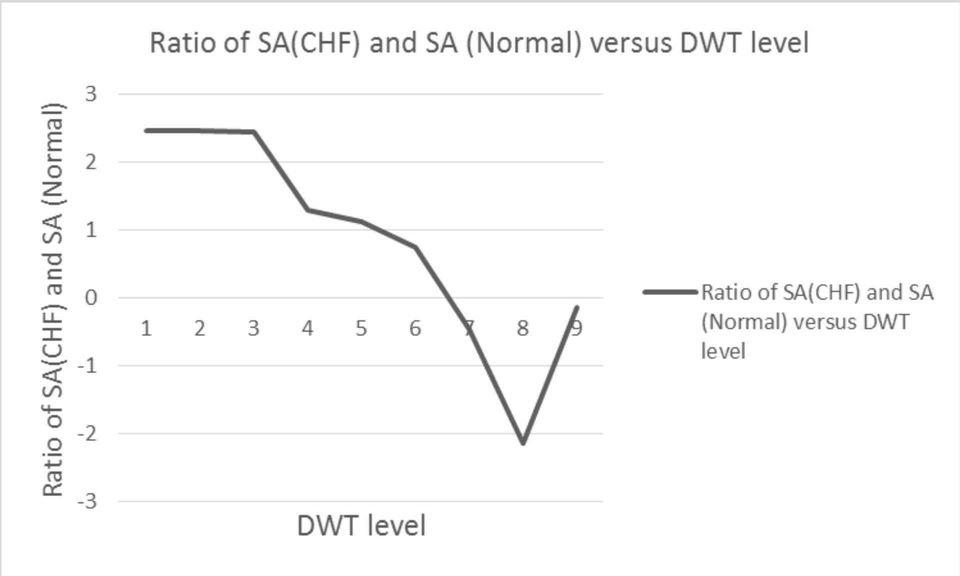


Fig. 2 The ratio for change of SA due to congestive heart failure

5. Skewness of Detail Coefficients

Detail coefficients have been determined at each DWT level of 1 to 9 for electrocardiogram signals collected from normal person as well as patients suffering from Congestive Heart Failure (CHF). For each level Skewness of Detail Coefficients (SD) has been determined. SD values obtained for normal person and CHF patient have been presented in Table 2. To show the changes of SD of CHF with respect to SD of normal person, the ratio of these values have been calculated at each level. At ith DWT level, the ratio for change of SD can be written as follows:

$$R_{SD_i} = \frac{SD_{CHF_i}}{SD_{N_i}} \qquad (2)$$

With the help of SD_{CHF_i} and SD_{N_i}, the ratio R_{SD_i} corresponding to change of skewness of detail coefficient in ith DWT level has been calculated and present in Table 2.

Table-2

Skewness of detail coefficients

DWT Level	SD for Normal SD_{N_i}	SD for CHF SD_{CHF_i}	$R_{SD_i} = \frac{SD_{CHF_i}}{SD_{N_i}}$
1	-0.43	0.019	-0.04

2	-0.49	0.06	-0.12
3	0.43	0.49	1.14
4	0.49	1.02	2.08
5	1.08	0.16	0.15
6	0.85	0.19	0.22
7	0.24	0.04	0.17
8	0.17	0.12	0.75
9	0.23	0.20	0.87

SD values for normal person and CHF patient of Table 2 have been plotted in bar chart as shown in Fig. 3. It shows that SD for CHF patient is higher at DWT level 3 with small difference and at DWT level 4 with large difference. At all other DWT levels, magnitudes of SD of normal person is greater than that of CHF patient; at DWT level 1 and 2, they are of opposite direction.

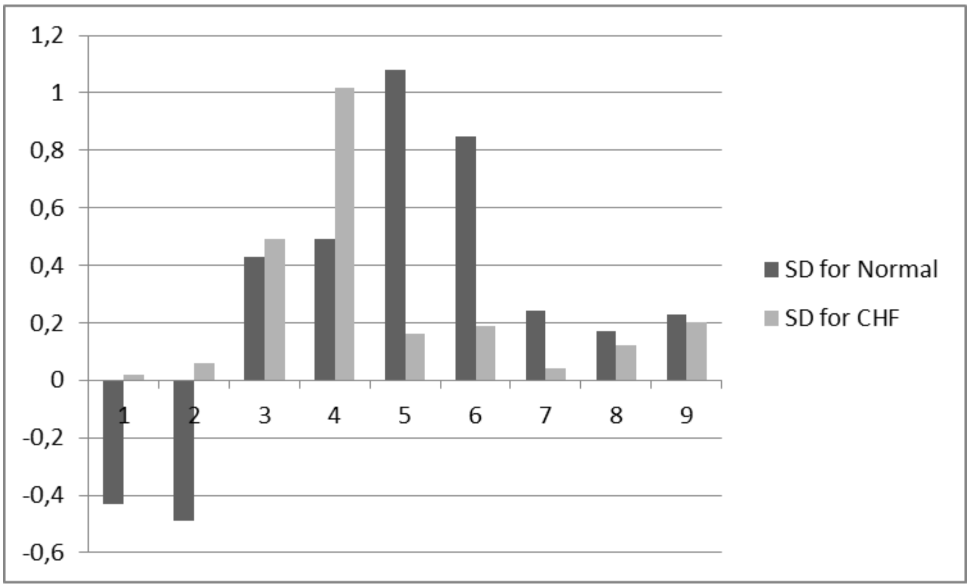


Fig. 3 SD of normal person and CHF patient

The ratio for change of SA due to congestive heart failure has been shown in Fig. 4. It shows that R_{SD_i} is negative at DWT level 1 and 2: for all other levels the ratio is positive. It becomes maximum and positive at DWT level 4 which may be used for detection of

CHF. Thus from this figure it may be concluded that there may be possibility of CHF if $R_{SD_4} = Positive\ and\ > +2$.

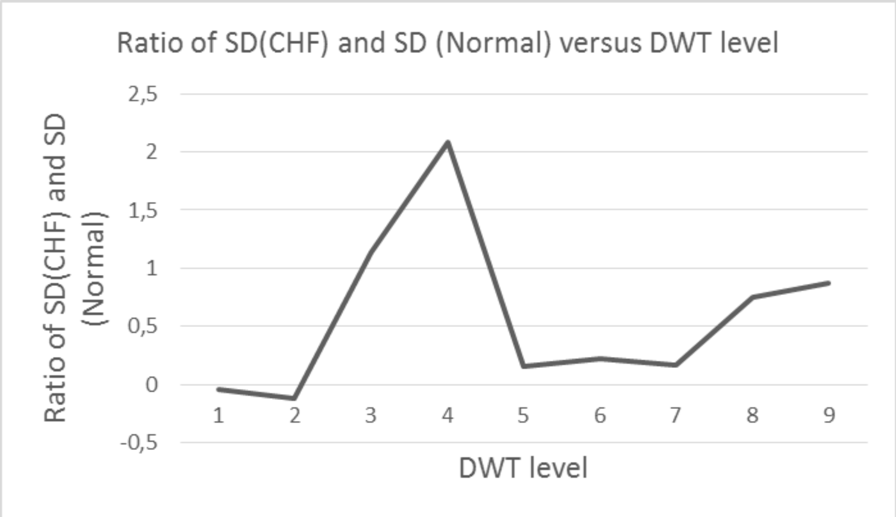


Fig. 4 The ratio for change of SD due to congestive heart failure

5. Radar Comparison

Radars of SA and SD have been developed for comparative study. Radars of SA corresponding to normal person and CHF patient have been shown in Fig. 5. It shows the change of shape radar of SA. Area of Radar of SA increases due to congestive heart failure and area of radar of SA is higher than that for normal person.

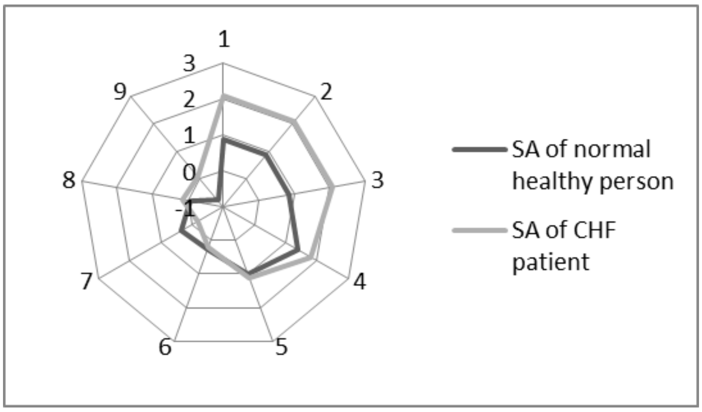


Fig. 5 Radars of SA for normal person and CHF patient

Radars of SD corresponding to normal person and CHF patient have been shown in Fig. 6. It shows the change of shape of radar of SD. Area of Radar of SD decreases due to congestive heart failure and area of radar of SD is less than that for normal person.

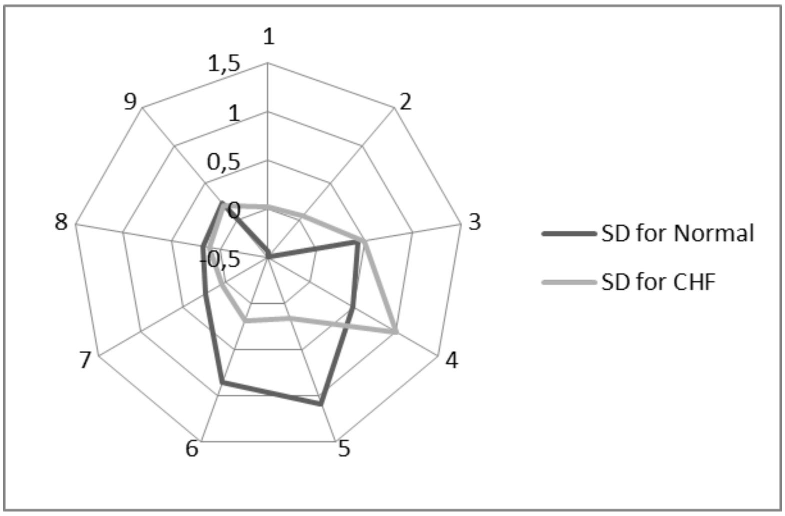
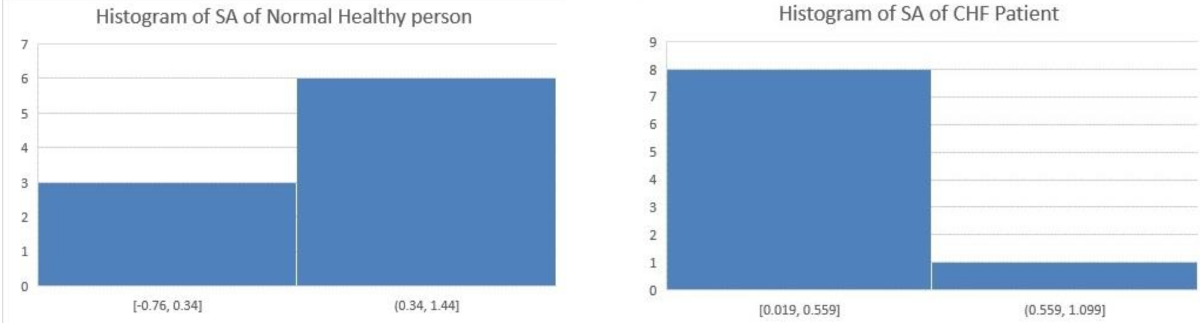


Fig. 6 Radars of SD for normal person and CHF patient

6. Histogram Assessment of SA and SD

Histogram of SA and SD has been developed for comparative study. Histograms of SA and SD have been shown in Fig. 7 as developed by statistical parameters obtained from approximate and detail coefficients resulted from wavelet decomposition of electrocardiogram signals of normal person and heart patients suffering from congestive heart diseases. Fig. 7(a), 7(b), 7(c) and 7(d) show histogram of SA for normal person, histogram of SA for CHF patients, histogram of SD for normal person and histogram of SD for CHF patient respectively. It shows that peaks of histograms for both SA and SD for CHF patients are higher than peaks of histograms of SA and SD for normal person whereas, minimum of heights of histograms of SA and SD for CHF patients are lower than minimum heights of histograms of normal person. These differences coming from the study of histogram of DWT based statistical parameters may be useful in classification of electrocardiogram signals with reference to congestive heart failure.



(a) (b)

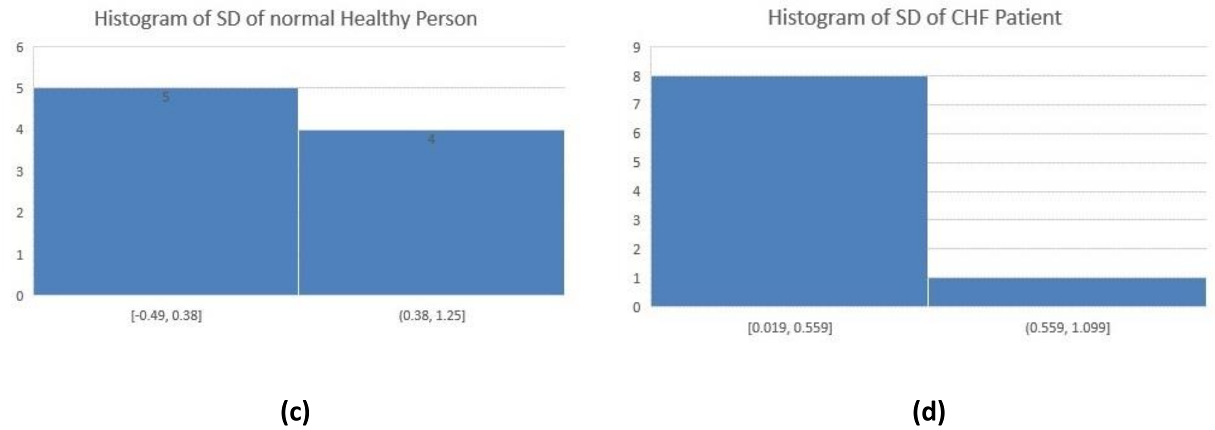


Fig. 7 Histogram of (a) SA for normal person, (b) SA for CHF patients, (c) SD for normal and (d) SD for CHF patients

7. Conclusion

Study of effect of congestive heart failure on electrocardiogram by discrete wavelet transformation based analysis of electrocardiogram has been carried out along with its diagnosis. Data of electrocardiogram from normal person as well as patient suffering from congestive heart failure have been collected from standard data bank and used for analysis. Statistical behavior of wavelet coefficients have been analyzed by their skewness values both for normal person and patient suffering from congestive heart failure. Comparative study has been carried out by corresponding radar diagram and histogram which shows significant difference due to heart failure.

REFERENCES

[1] Martin O. Mendez*; Anna Maria Bianchi; Matteo Matteucci; Sergio Cerutti; Thomas Penzel, Sleep Apnea Screening by Autoregressive Models From a Single ECG Lead, IEEE Transactions on Biomedical Engineering, Year: 2009, Volume: 56, Issue: 12
Pages: 2838 - 2850, DOI: 10.1109/TBME.2009.2029563.

[2] S Mitra, M. Mitra, S Chattopadhyay, S Sengupta, An Approach to a Rough Set Decision System for Classification of Different Heart Diseases, MS-04, Lyon, France, 5-9 July, 2005, PP 1.17-1.20.

[3] Lili Chen; Xi Zhang; Changyue Song, An Automatic Screening Approach for Obstructive Sleep Apnea Diagnosis based on Single-Lead Electrocardiogram, IEEE Transactions on Automation Science and Engineering, Year: 2015, Volume: 12, Issue: 1, Pages: 106 - 115, DOI: 10.1109/TASE.2014.2345667.

[4] Ali Jezzini; Mohammad Ayache; Lina Elkhansa; Zein al abidin Ibrahim, ECG classification for sleep apnea detection, 2015 International Conference on Advances in Biomedical Engineering (ICABME), Year: 2015, Pages: 301 -304, DOI: 10.1109/ICABME. 2015.7323312.

[5] Ahnaf Rashik Hassan; Mohammad Aynal Haque, Computer-aided sleep apnea diagnosis from single-lead electrocardiogram using Dual Tree Complex Wavelet Transform and spectral features, International Conference on Electrical & Electronic Engineering (ICEEE), Year: 2015, Pages: 49 - 52, DOI: 10.1109/CEEE.2015.7428289.

[6] H Masum, S Chattopadhyay, S Bhaumik, R Ray, Utilization of Skewness of Wavelet based Approximate Coefficient in Walking Speed Assessment, IET Science, Measurement & Technology, 12 pp, DOI:10.1049/iet-smt.2016.0263, Online ISSN 1751-8830 Available online: 03 August 2016.

[7] Santanu Chattopadhyay, R.R. Majhi, S. Chattopadhyay, A. Ghosh, Analysis of Electro-Cardiogram by Radar and DWT based Kurtosis Comparison, Michael Faraday IET International Summit 2015, 2015 page 108 (5 .), DOI: 10.1049/cp.2015.1704, ISBN: 978-1-78561-186-5, Kolkata, India, Conference date: 12-13 Sept. 2015.

[8] Santanu Chattopadhyay, R.R. Majhi, S. Chattopadhyay, A. Ghosh, Radar Assessment of Wavelet decomposition based Skewness of ECG Signals, Michael Faraday IET International Summit 2015, 2015 page 109 (5 .), DOI: 10.1049/cp.2015.1705, ISBN: 978-1-78561-186-5, Kolkata, India, Conference date: 12-13 Sept. 2015.

[9] S Chattopadhyay, S Chattopadhyay, A Das, Electrocardiogram Signal Analysis for Diagnosis of Apnea, AMSE JOURNALS-Series: Modeling C; Chemistry, Geology, Environment and Bioengineering, ISSN: 1259-5977, Vol, 77; No 1; pp 28-40, 2016.

[10] Santanu Chattopadhyay, Gautam Sarkar, Arabinda Das, Spider and Histogram Assessment of Electrocardiogram for Apnea Diagnosis, International conference of IMBIC MSAST-2016, ISBN 978-81-925832-4-2,Volume 5(2016),Page:149-153.

[11] Santanu Chattopadhyay, Gautam Sarkar, Arabinda Das, Study of Arrhythmia using Wavelet Transformation based Statistical Parameter Computation of Electrocardiogram Signal, Proceedings of International conference on Modelling and Simulation (MS-17), Kolkata, India, Paper ID 139, November 4-5, 2017.

[12] Santanu Chattopadhyay, Gautam Sarkar, Arabinda Das, Electrocardiogram Signal Analysis for Diagnosis of Congestive Heart Failure, Proceedings of International conference on Modelling and Simulation (MS-17), Kolkata, India, Paper ID 133, November 4-5, 2017.