International Journal of Soft Computing and Engineering (IJSCE)
ISSN: 2231-2307, Volume-5 Issue-1, March 2015

Detection of Rpeak Index and Characterization of QRS Complex of the ECG Signal using Virtual Instruments of Lab VIEW

Chandan Tamrakar, Chinmay Chandrakar, Monisha Sharma

Abstract*— In the ECG signals P, QRS and T waves play an essential role. Various features of these waves provide significant information to diagnose most of the cardiac diseases after preprocessing of the ECG signal. In various features, RR-interval, QRS Duration, and QRS sample Characteristic are the feature, which reveals significant information about the physiological conditions of the patient. In the previous work to find the RR-interval Discrete Wavelet Transform (DWT) technique and by applying a thresholding to peak detection method has been used. The proposed work is totally digital system based to for detection of consecutive Rpeaks in time domain and in the form of sample index finally the RR-interval has been calculated with the help of Waveform Min Max VI and Search Waveform VI of LabVIEW. In the previous work to detect QRS characteristics LabVIEW mathscript tool and simple moving average filter etc. method has been used. This paper deals with a resourceful composite system which has been proposed for detection of Rpeak Index and QRS Duration. In the proposed work QRS characteristics has been extracted from Extract Portion of the Signal VI of LabVIEW for the standard MIT-BIH arrhythmia database. LabVIEW 2013 version provided by National Instruments has been used here to design the feature extractor.

Index Terms*— Biomedical Signal, Detrending, Denoising, ECG, Feature extraction, LabVIEW, MIT-BIH arrhythmia database, RR-interval, Wavelet Analysis.

I. INTRODUCTION

The ECG signal is a representation of the bioelectrical activity of the heart representing the cyclical contractions and relaxations of the human heart muscles [7]. The ECG waveform consists of five different component waves, namely P, Q, R, S and T waves followed by a conditional U wave [10] as shown in fig.1. A number of techniques have been devised by the researchers to detect the characteristics in ECG Recently LabVIEW Virtual Instruments (VI) tool has been proven to be useful tool for non-stationary signal analysis.

Manuscript Received on February 16, 2015.
Chandan Tamrakar, Electronics & Telecommunication, Shri Shankaracharya College of Engineering & Technology, Bhilai, India.
Chinmay Chandrakar, Electronics & Telecommunication, Shri Shankaracharya College of Engineering & Technology, Bhilai, India.
Dr. Monisha Sharma, Electronics & Telecommunication, Shri Shankaracharya College of Engineering & Technology, Bhilai, India.

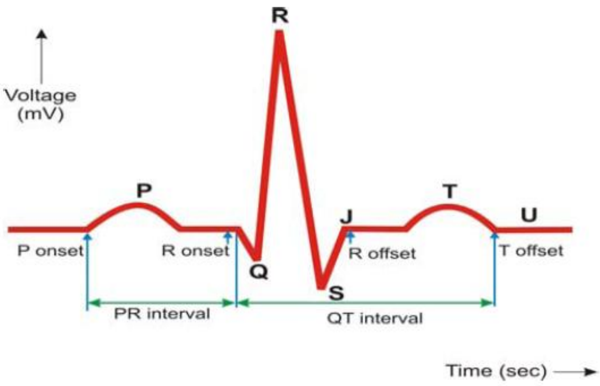

Fig.1. Normal ECG Signal

Jiapu Pan and Willis J. Tompkins [1] algorithm reliably detects QRS complexes using slope, amplitude, and width information. A band pass filter preprocesses the signal to reduce interference, permitting the use of low amplitude thresholds in order to get high detection sensitivity. Li et al. [2] detect the onsets and offsets of QRS complexes at scale 2^1. They can see that the onset of QRS corresponds to the beginning of the first modulus maximum before the modulus maximum pair created by the R wave, and the offset of QRS corresponds to the ending of the first modulus maximum after that modulus maximum pair. From the modulus maximum pair of the R wave, the beginning and ending of the first modulus maxima before and after the modulus maximum pair are detected within a time window (thresholds) to the wavelet transform of the ECG signal. Mahmoodabadi et al. [3] algorithm to detect the R wave, wavelet filters (D4 and D6) Details 2^3 – 2^5 were kept and all the details were removed. This procedure removed low frequencies and high frequencies. And to detect the Q and S peaks, in order to make the peaks noticeable, all the details of the signal were removed up to detail 2^5. The approximation signal remained, was searched for extermum points about the R peaks formerly detected. Chen et al. [4] proposed method employs a simple moving average filter for extracting the QRS feature from the denoised ECG data so the number of operations, i.e. multiplications and additions, required is less than that for most of the existing algorithms, thus allowing a simple and time-efficient realization of real-time QRS detection. Arzeno et al. [5] proposed the Hilbert transform is an odd filter, the zero-crossings of the differentiated ECG, which correspond to the R-peaks, will be represented as peaks in the output of the transform. The Hilbert transform's all-pass characteristic prevents unnecessary signal distortion, in contrast to the second derivative method which tends to attenuate the signal at the lower frequencies. Thus, the odd-phase component of the filter provides the necessary rectification of the differentiated ECG signal in order to identify the QRS peaks while the uniform magnitude of the filter ensures that necessary information of the QRS complexes is preserved. Bhyri et al.[6] proposed algorithm one peak detector is used for R wave, once the R peaks are detected, with reference to this peak the signal is scanned for 50 msec on the left side to get the minimum value and this corresponds to Q peak. Similarly the minimum value on the right side of the R peak corresponds to S peak. This procedure is implemented using mathscript. Mathscript is a LabVIEW tool for executing textual mathematical commands (or expressions). Faezipour et al. [7] algorithm marks peaks that are above zero and valleys that are below zero by the help of WA Multiscale Peak/Valley Detection VI in LabVIEW. This particular VI uses the Multiresolution wavelet analysis to detect peaks or valleys of a signal. By determining local maxima above a predefined threshold or local minima below the threshold value, these peaks or valleys can be extracted in this VI. Noack et al. [9] proposed cluster method is based on a procedure described by Schwenker et al. as adaptive cluster analysis. This keeps the cluster representation adapted to the current input data stream, always having a good representation of the actual QRS complexes.

The present work has been proposed that Wavelet Analysis (WA) Detrend Virtual Instrument (VI) which can be used to remove the low frequency baseline wandering (or trend) of a signal using the sym5 wavelet. After Detrending Wavelet denoise VI is considered with undecimated wavelet transform (UWT) sym5 and multiple levels on the detrended signal to make only the QRS complexes of the signal more distinct. The Rpeak Index has been detected by Array Min Max VI without and adaptive thresholding and valleys (Q and S point) has been detected by Extract Portion of Signal Express VI of LabVIEW. All beat detection is based on sample values. After the detection of Q, Rpeak and S beat, the features QRS duration (in samples) has been calculated.

The MIT-BIH arrhythmia database is used in the study for performance assessment. The database contains 48 records. The ECG signals for 30 min duration selected from 24-hr recordings of 47 individuals. There are 116,137 numbers of QRS complexes in the database [11].

LabVIEW (Laboratory Virtual Instrument Engineering Workbench) designed by National Instruments that is specially for easy and powerful data acquisition purpose. LabVIEW software is used for data recording and visualization, due to its known capabilities [8]

II. METHODOLOGY

A. MIT-BIH Arrhythmia ECG data base:

For execution of feature extraction process the ECG signal is acquired from MIT-BIH arrhythmia data base. The Read Biosignal VI is provided by LabVIEW to import the ECG signal in the ".hea" format.

B. Preprocessing

The preprocessing of ECG signal consist Detrending and Denoising, which are explained below:

i. Detrending

Baseline wandering usually comes from respiration at frequency wandering between 0.15Hz and 0.3Hz and it can be suppressed by a high pass digital filter. Wavelet transform can also be used to remove the baseline wandering by eliminating the trend of the ECG signal. The LabVIEW Advanced Signal Processing Toolkit (ASPT) provides the WA Detrend Virtual Instrument (VI) which can be used to remove the low-frequency baseline wandering (or trend) of a signal. In the WA Detrend VI, there has been also suggested using the sym5 wavelet as it resembles the QRS complex of ECG more than the other type of wavelets. An internal parameter called trend level is required for baseline removal. The trend level is calculated as follows:

$$\text{LEVEL Trend} = \frac{\log_2 2t}{\log_2 N} \qquad (1)$$

Where, t is the observation duration and N is the number of sampling points in observation time t [8]. Here an analysis of 'one' second duration signal with 360 sampling points has been done and this consideration leads to the value of trend level to 0.1178Hz. In the WA Detrend VI the threshold frequency equal to 0.1178 Hz is used and the selected wavelet is symmlet5 (sym5).

ii. Denoising

Bhyri et al. [6] used Daubechies (db06) wavelet because this wavelet is similar to the real ECG signal and also Daubechies wavelet being orthogonal wavelet is suitable for signal denoising where as biorthogonal wavelet is suitable for signal feature extraction.

The undecimated wavelet transform (UWT) sym5 with single level and soft thresholding for the wavelet denoising VI block setup has been used. UWT results in the approximation wavelet coefficients and the detail coefficients at all decomposition levels. As UWT has the shift invariant property, it is highly efficient in robust-feature extraction applications. In addition, peak detection using UWT-based methods are more robust and less sensitive to noise, since UWT-based methods find zero-crossings in the multiscale UWT coefficients. These settings perform efficient denoising on the original ECG signal and smoothens the signal without suppressing ECG features such as the P and T waves. For effective feature extraction, the application of wavelet denoise VI is considered with UWT (Undecimated Wavelet Transform) symmlet5 (sym5) and multiple levels on the detrended signal to make only the QRS complexes of the signal more distinct.

C. Analog to Digital Conversion:

In this process an Analog to Digital VI has been used, which convert an analog ECG signal into 2 volt peak to peak, 8 bit resolution digital data.

D. Digital to Binary conversion:

In this process a digital data is converted into binary array. To convert into binary a "Digital to Binary VI" has been used.

E. Rpeak Sample Index Detection:

Faezipour et al. [7] consider Peak as the array of peaks that Lab VIEW peak-detector VI has found. A signal peak that is larger than the threshold THR is considered as a QRS complex, where the R point is detected. Each time a beat (R point) is found. In the present proposed work a "Min Max VI" has been used, which provides the Rpeak voltage value and Rpeak array sample value. Rpeak value is always according to resolution 28-1 i.e. 255. Due to quantization of sampled value there also few 255 quantized values occur. To detect original Rpeak having value 255, analog waveform Min max VI and Search waveform VI has been used. With the help of these VIs accurate Rpeak has been detected for further processing like QRS detection

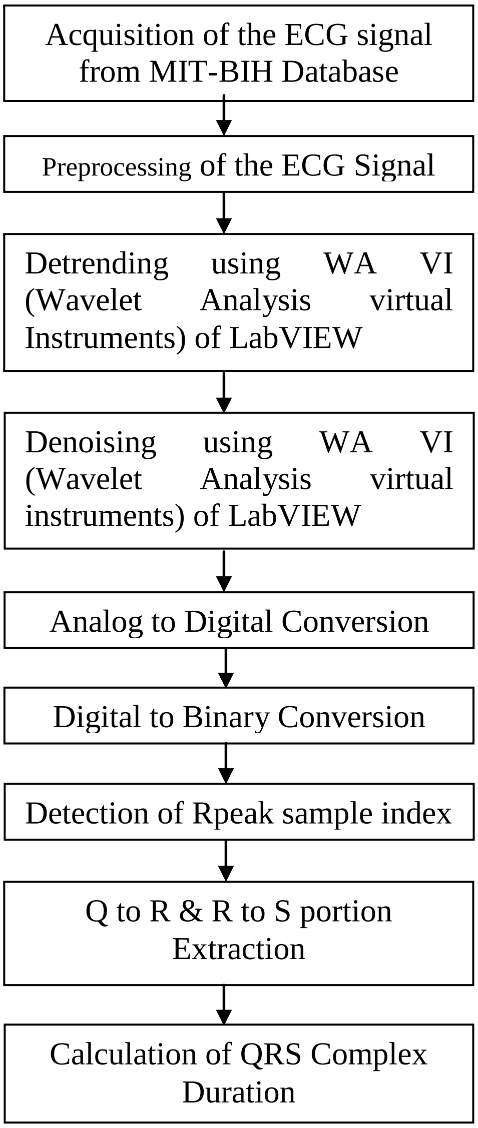

Fig.2. Data flow diagram of the proposed work

To find the Q and S beats of the ECG waveform, Faezipour et al. [7] Applies underlying concept that a Q point is the closest valley right before R point, and an S point is the closest valley right after a detected R point. The valley locations are found using the WA peak/valley detector with zero as the threshold. But the present proposed work is as follows:

F. Extraction of Q-R portion:

The binary array of an ECG signal is given to Extract Q-R portion VI. "Extract Q-R portion VI" provides the binary array of Q to R beats. It searches the Q beat which located at left side of R beat and having the lowest sample resolution value. This VI also provides sum of sample resolution value of Q to R beat.

G. Extraction of Q-R portion:

The binary array of an ECG signal is given to Extract R-S portion VI. "Extract R-S portion VI" provides the binary array of R to S beats. It searches the S beat which located at right side of R beat and having the lowest sample resolution value. This VI also provides sum of sample resolution value of R to S beat.

To characterize the QRS complex of ECG signal Faezipour et al. [7] used chose a fixed timeframe of 150 ms centered at the R point, which empirically corresponds to the largest QRS complex. Since multiple metrics are used here to quantify certain features of a heartbeat, a (hash) function such as the summation of these quantities can be used to compact each instance (useful information between the borders of analysis) in a single string of data. The present proposed work is as follows:

H. Get QRS Duration in the form of Array Samples:

With the knowledge of Q and S beat location in the form of sample number, the QRS duration has been found

$$\text{QRS Duration} = \text{Sample no. of S beat} - \text{Sample no. of Q beat} \qquad (2)$$

III. RESULT

A. Preprocessing Result:

The test ECG signal is shown is fig. 3. This ECG is acquired from MIT- BIH database. The signal contains various noises, which are removed in preprocessing process.

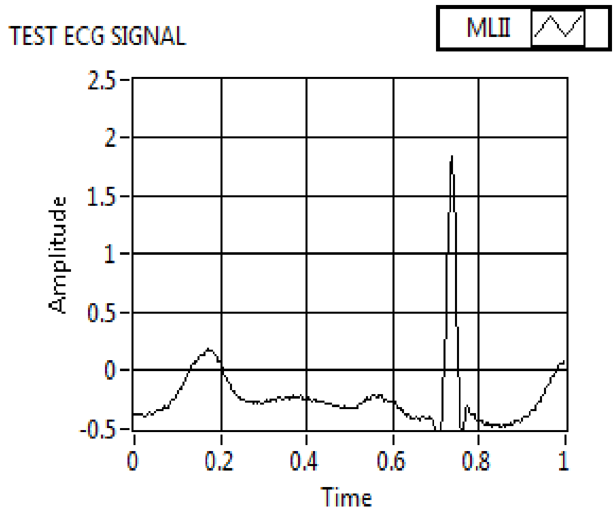

Fig.3. Test ECG signal

The Baseline wondering (or trend) removed ECG signal is shown if fig.4.

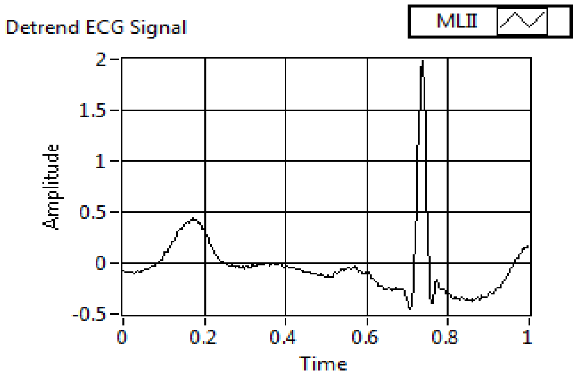

Fig.4. Detrend ECG signal

After avoiding the Baseline wondering (or trends), the denoising process is done and the denoised signal is shown in fig.5.

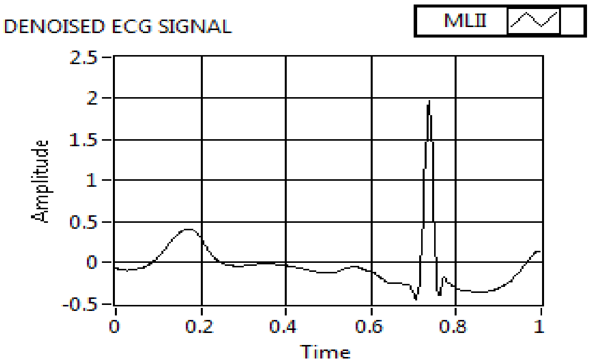

Fig.5. Denoised ECG Signal

B. Detected Rpeak Index and Various Features:

Table 1: Feature Value

R_{peak} Time (in msec)	R_{peak} Index (in samples)	R-R Interval (in msec)	QRS Duration (in msec)	QRS Duration (in samples)
0	0	0.194444	72.22222	26
0.194444	70	0.833333	75	27
1.027778	370	0.85	77.77778	28
1.877778	676	0.847222	80.55556	29
2.725	981	0.844444	80.55556	29
3.569444	1285	0.844444	80.55556	29
4.413889	1589	0.811111	72.22222	26
5.225	1881	0.822222	80.55556	29
6.047222	2177	0.833333	72.22222	26
6.880556	2477	0.808333	80.55556	29
7.688889	2768	0.797222	80.55556	29
8.486111	3055	0.863889	69.44444	25
9.35	3366	0.861111	80.55556	29
10.21111	3676	0.844444	75	27
11.05556	3980	0.844444	80.55556	29
11.9	4284	0.827778	80.55556	29
12.72778	4582	0.841667	80.55556	29
13.56944	4885	0.8	77.77778	28
14.36944	5173	0.813889	72.22222	26
15.18333	5466	0.827778	63.88889	23
16.01111	5764	0.819444	80.55556	29
16.83056	6059	0.813889	80.55556	29
17.64444	6352	0.816667	80.55556	29
18.46111	6646	0.791667	80.55556	29
19.25278	6931	0.791667	80.55556	29
20.04444	7216	0.808333	80.55556	29
20.85278	7507	0.8	80.55556	29
21.65278	7795	0.802778	80.55556	29
22.45556	8084	0.819444	80.55556	29
23.275	8379	0.797222	77.77778	28
24.07222	8666	0.838889	77.77778	28
24.91111	8968	0.830556	80.55556	29
25.74167	9267	0.830556	72.22222	26
26.57222	9566	0.863889	69.44444	25
27.43611	9877	0.838889	75	27
28.275	10179	0.838889	69.44444	25
29.11389	10481	0.861111	66.66667	24
29.975	10791	0.652778	80.55556	29
30.62778	11026	0.994444	69.44444	25
31.62222	11384	0.847222	63.88889	23
32.46944	11689	0.844444	66.66667	24
33.31389	11993	0.838889	66.66667	24
34.15278	12295	0.836111	63.88889	23
34.98889	12596	0.844444	63.88889	23
35.83333	12900	0.836111	66.66667	24
36.66944	13201	0.827778	80.55556	29
37.49722	13499	0.813889	80.55556	29
38.31111	13792	0.777778	80.55556	29
39.08889	14072	0.8	80.55556	29
39.88889	14360	0.775	66.66667	24
40.66389	14639	0.772222	75	27
41.43611	14917	0.816667	69.44444	25
42.25278	15211	0.797222	63.88889	23
43.05	15498	0.813889	61.11111	22
43.86389	15791	0.833333	66.66667	24
44.69722	16091	0.844444	61.11111	22
45.54167	16395	0.852778	63.88889	23
46.39444	16702	0.847222	63.88889	23
47.24167	17007	0.855556	63.88889	23
48.09722	17315	0.858333	61.11111	22
48.95556	17624	0.863889	61.11111	22
49.81944	17935	0.858333	66.66667	24
50.67778	18244	0.85	63.88889	23
51.52778	18550	0.85	63.88889	23
52.37778	18856	0.838889	63.88889	23
53.21667	19158	0.838889	63.88889	23
54.05556	19460	0.841667	58.33333	21
54.89722	19763	0.816667	61.11111	22
55.71389	20057	0.847222	63.88889	23
56.56111	20362	0.819444	61.11111	22
57.38056	20657	0.838889	63.88889	23
58.21944	20959	0.858333	61.11111	22
59.07778	21268	0.833333	61.11111	22
59.91111	21568	0.838889	63.88889	23

The result shows that the detected Rpeak Sample index (in samples) with their time value (in msec). R-R interval (in msec). Also it provides the QRS complex Duration in terms of no. of Samples with their respective time value (in msec). The result shows that because of non stationary nature of ECG signal there will be variation in QRS complex duration. The Rpeak time and Rpeak sample index has been detected by the proposed methodology as shown in Table

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

1 is verified from MIT-BIH Arrhythmia Databas (PhysioNet [12])

Table 2: Comparison with previous work

S. No.	Previous Work	Proposed Work
1.	Bhyri et al. (2009) Daubechies(db06) wavelet used for detrending	Symmlet5(sym5) Wavelet use for detrending
2.	Bhyri et al. (2009) used 8 level Daubechies (db06) wavelets	undecimated wavelet transform (UWT) sym5 and multiple levels
3.	Faezipour et al. (2010) used Adaptive thresholding required	Adaptive thresholding not required
4.	Faezipour et al. (2010) used Peak Detector VI	Waveform Min Max VI
5.	Bhyri et al. (2009) Mathscript required	Extract Portion of Signal Express VI
6.	Faezipour et al. (2010) used W = 150 ms: the size of the sliding window around QRS region	Adaptive window to extract QRS Duration

IV. CONCLUSION

In this paper the development of feature extractor for the ECG signal using LabVIEW VI (virtual Instrument) is proposed. For this, the input signals is imported from MIT-BIH Arrhythmia data base are properly preprocessed by WA (Wavelet Analysis) detrend VI and Wavelet Denoise Express VI. In the proposed work there is an advantage that there is no use of any thresholding technique which avoided the reduction sensitivity in QRS detection. The proposed work use adaptive window to extract the QRS Duration. This is a novel technique that can be used for ECG profiling and ECG beat classification.

REFERENCES

1. Jiapu Pan and willis j. Tompkins, "A Real-Time QRS Detection Algorithm" IEEE transactions on biomedical engineering, vol. BME-32, no. 3, pp. 230-236, march 1985.
2. Cuiwei Li, Chongxun Zheng, and Changfeng Tai "Detection of ECG Characteristic Points Using Wavelet Transforms" IEEE Transactions on Biomedical Engineering, Vol. 42, No. 1, January 1995 pp.21-28
3. S. Z. Mahmoodabadi, A. Ahmadian, and M. D. Abolhasani, "ECG Feature Extraction using Daubechies Wavelets", Proceedings of the fifth IASTED International conference on Visualization, Imaging and Image Processing, pp. 343-348,2005
4. Szi-Wen Chena, Hsiao-Chen Chena, Hsiao-Lung Chanb "A real-time QRS detection method based on moving averaging incorporating with wavelet denoising" computer methods and programs in biomedicine 82 (2006) 187–195.
5. Natalia M. Arzeno, Zhi-De Deng, and Chi-Sang Poon, Analysis of First-Derivative Based QRS Detection Algorithms IEEE Transactions on Biomedical Engineering, Vol. 55, No. 2, February 2008, pp.478-484
6. Channappa Bhyri, Kalpana.V, S.T.Hamde, and L.M.Waghmare "Estimation of ECG features using LabVIEW", TECHNIA – International Journal of Computing Science and Communication Technologies, VOL. 2, NO. 1, pp. 320-324, July 2009
7. Faezipour, Student, Adnan Saeed, Suma Chandrika Bulusu,Mehrdad Nourani, Hlaing Minn, and Lakshman Tamil, "A Patient-Adaptive Profiling Schemefor ECG Beat Classification", transactions on information technology in biomedicine, vol. 14, no. 5, pp. 1153-1165, September 2010.
8. M. K. Islam, A. N. M. M. Haque, G. Tangim, T. Ahammad, and M. R. H. Khondokar, (2012). "Study and Analysis of ECG Signal Using MATLAB & LABVIEW as Effective Tools", International Journal of Computer and Electrical Engineering, Vol. 4, No. 3, pp. 404-408 June.
9. A. Noack, R. Poll, W.-J. Fischer, S. Zaunseder, "QRS Pattern Recognition Using a Simple Clustering Approach for Continuous Data" 2013 IEEE XXXIII International Scientific Conference Electronics and Nanotechnology (ELNANO), pp. 228-232
10. Swati Banerjee and M. Mitra, (2013). "ECG beat classification based on discrete wavelet transformation and nearest neighbour classifier", J Med Eng. Technol, 37(4).pp.264–27
11. http://www.physionet.org/physiotools/wag/wag.pdf
12. http://www.physionet.org/cgi-bin/atm/ATM?database=mitdb&tool=plot_waveforms

AUTHORS PROFILE

Chandan Tamrakar is currently an Assistant Professor in Electronics and Telecommunication at Shri Shankaracharya College of Engineering and Technology, Bhilai. He received his B.E. Degree in Electronics and Telecommunication from Chhattisgarh Swami Vivekanand Technical University, Bhilai, India in 2010. His area of interest is Biomedical Signal Processing.

Mr. Chinmay Chandrakar is currently working as a Senior Associate Professor in Electronics and Telecommunication at Shri Shankaracharaya College of Engineering and Technology, Bhilai. He received his B.E in Electronics from Nagpur University, India in1997. Then he received a Post Graduate Degree in Computer Technology from Pt. Ravi Shankar University, Raipur in 2002. His research area interest includes Digital Signal Processing and its application in the field of Biomedical.

Dr. Monisha Sharma is currently working as a Professor in Electronics and Telecommunication at Shri Shankaracharaya College of Engineering and Technology, Bhilai. She received her B.E in Electronics and Telecommunication from Pt. Ravi Shankar University, Raipur, India in 2000.She also received a post graduate Degree in Instrumentation from CSVTU, Bhilai, in 2007. The she obtained her PhD from Swami Vivekananda Technical University, Bhilai, India in 2010.