Use of ANFIS based Filters For Reduction of Noise From Biomedical Signals

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Abstract—Biomedical signals are the collection of electrical signals acquired from any organ of human body. These signals acquire noise while traveling through different tissues or blood vessels.Similarly,these signals are affected by electrical noise and some other factors. Electrical noise included inherent noise in Electronicequipments, ambient noise, motion artifacts, power line interference, base line drift, electrosurgical noise and inherent instability of signal. By using conventional methods, it is very difficult to reduce noise from biomedical signal.Therefore different methodologies are used to remove noise and artifacts. This paper describes the adaptive filters and adaptive network based fuzzy inference system (ANFIS) filters which are used to reduce noise from biomedical signals.

Keywords- Adaptive filter, AI, ANFIS,LMS, SLMS, SSLMS,NLMS, NSLMS

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I. INTRODUCTION

Biomedical signal means a collective electrical signal acquired from any organ that represents a physical variable of interest. This signal is normally a function of time and is described in terms of its amplitude, frequency, and phase.The analysis of these signals is very important for researchers and medical practitioners because careful medical diagnosis isvery essential for proper treatment. If the signals are not properly diagnosed and analyzed, it will lead to wrong diagnosis and can be dangerous for the lives.

The biomedicalsignals are noisy as well as artifacts due to electrical noise included inherent noise in Electronicequipments, ambient noise, motion artifacts, power line interference, base line drift, electrosurgical noise and inherent instability of signal. This reduces the performance of desired signal.Therefore for the proper treatment of a patient, it should be removed from the desired signal. Using an amplifier with high gain, high input impedance and differential input with good common mode rejection, various filter circuits could reduce the noise from biomedical signals. But using conventional method, it is difficult to reduce maximum noise from biomedical signal. Therefore there is a need of intelligent solution for this.

In fact, various mathematical techniques and Artificial Intelligence approaches are being used for noise reduction.Literature reviews show that in nonlinear system identification, a mathematical model includes Wavelet Transform, Time Frequency Approaches, Fourier Transforms, Wegner-Villie Distribution, Statistical Measures and Higher Order Statistics. AI includes artificial neural network, dynamic recurrent neural network, Fuzzy logic system and genetic algorithm.Accuracy of biomedical signal also depends on the properties of electrodes and their interaction with skin, amplifier design, the conversion and subsequent storage of the biomedical signal from analog to digital form.

In the recent years, biomedical applications using signal processing techniques are a major area of interest. The lot of bio-engineers and researchers from medical field are keenly interested for design of techniques to obtain noiseless biomedical signals. R. Sehamby andButa Singh (2016) [14] have designed the adaptive electrocardiogram filter to reduce noise caused by external systems & body artifacts.R. J.George (2015) [12] reveals in his study that the pipelined DLMS adaptive FIR filter is faster than non-pipelined LMS adaptive FIR filter.S. Silarbi, B. Abderrahmane and A. Benyettou (2014) [17] have proposed adaptive network fuzzy inference system for phonemes recognition.H. K. Gupta, R. Vijay and N. Gupta (2013) [5] have observed that the accuracy has been increased by increasing filter order as well as with increased in step size, convergence rate took place fast. B. Chandrakar, O. P. Yadav and V. K. Chandra (2013) [10] havestudied Finite Impulse Response (FIR) filter based on various windows and Infinite Impulse Response (IIR) filters for noise removal of ECG signal.The researcherD. C. Dhubkarya andA.Katara[13] have studied the comparison of MATLAB Simulation and DSP Processor implementation of an adaptive filter on Least Mean Squared (LMS) and Normalized Least Mean Squared (NLMS) Algorithms. They suggested NLMS algorithm is superior in hardware implementation.

Jyh-Shing Roger Jang (1993) [18] suggested that the role of neural networks in signal processing have similar applications in Adaptive network based fuzzy inference system (ANFIS). The nonlinear and structured knowledge representation of ANFIS are the primary advantages over classical linear approaches in adaptive filtering and adaptive signal processing such as identification, inverse modeling, predictive coding, adaptive channel equalization, adaptive inference (noise or echo)cancelling, etc.

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II. SOFTWARE SPECIFICATION REQUIREMENT ANDIMPLEMENTATION DETAILS

In real life situations, the accuracy of the measurement is required. As we know that biomedical signals are error prone due to complicated situations. ANFIS can be used to obtain reasonably good accuracy and intelligently reduce the noise. In this section, we have simulated the MATLAB codes for the data conversion, adaptive filter algorithm, artificial intelligent [ANFIS] training and its testing.

Database collection:

To design ANFIS Model, a sufficiently large amount of data is required for training and testing. We have collected standard data bases for biomedical signal from the following websites.

https://physionet.org
http://www.emglab.net
https://drive.google.com/file/d/0B3NaVR72FYQcaHAybXVCZ0ViVVk/view.

We have used 500 samples for the training and testing of Adaptive filters and ANFIS based filters.

Software specification:

MATLAB (Matrix Laboratory), 2014b is used for simulation. It is a numerical computing environment and fourth-generation programming language developed by Math-Works. MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, Java, and FORTRAN.

Implementation details:

The GUI is constructed by using Matlab codes. Other set of codes have been used to run the various algorithms for noise removal in Matlab simulator.

The main GUI contains four parts-
1] File input and its conversion
2] Adaptive filter algorithm and its Input parameter section
3] Output parameters section
4] Artificial intelligent noise removal section.

File input and its conversion:

Most of the data bases are available in .dat or .xls format. To read this in Matlab, we have designed a code which will convert and save the .dat file or .xls file in .mat file format.

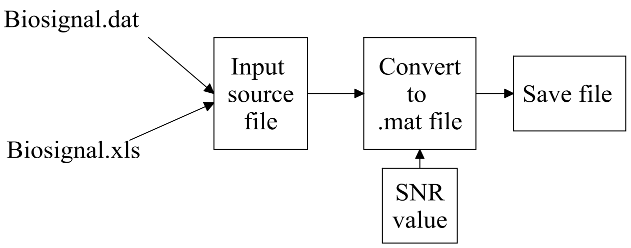

Figure 1: Block diagram of conversion of .dat and .xls files into .m files.

Adaptive filter section and its Input parameter section:

There are numerous Adaptive filter algorithms [22], out of which 5 algorithms were used. These are

1] Adaptive Least Mean Square (LMS) Algorithm:

If $w(n)$ is the filter coefficient vector at step n (time), then its' updated value $w(n+1)$ is given by

$$w(n+1) = w(n) + 2\mu\, e(n)\, x(n)$$

Where, Filter output $y(n) = w^T(n)\, x(n)$

Error$e(n) = d(n) - x(n)$

Filter taps at time n, $w(n) = [w_0(n)\ w_1(n) \ldots\ldots\ldots\ w_{M-1}(n)]$ and

Input data, $x(n) = [x(n)\ x(n-1) \ldots\ldots\ldots\ x(n-(M+1))]^T$

2] Adaptive Normalized LMS Algorithm:

The updated value $w(n+1)$ is given by

$$w(n+1) = w(n) + \frac{1}{x^T(n)\, x(n)}\, e(n)\, x(n)$$

with

$$\mu(n) = \frac{1}{2\, x^T(n)\, x(n)}$$

3] Adaptive Sign LMS Algorithm:

The updated value $w(n+1)$ is given by

$$w(n+1) = w(n) + 2\mu\, e(n)\, \mathrm{Sign}(x(n))$$

4] Adaptive Sign Sign LMS Algorithm:

The updated value $w(n+1)$ is given by

$$w(n+1) = w(n) + 2\mu\, \mathrm{Sign}(e(n))\mathrm{Sign}(x(n))$$

5] Adaptive Normalized Sign LMS Algorithm:

The updated value $w(n+1)$ is given by

$$w(n+1) = w(n) + 2\mu \frac{\mathrm{Sign}(e(n)\, x(n))}{\left|\left|x(n)\right|\right|^2}$$

Output parameter section:

The performance of ANFIS is assessed on the basis of performance parameters Signal to Noise Ratio (SNR_out). The output SNR (SNR_out), is calculated from the power of input signal x (n) and noise signal e (n) and is given by,

$$\mathrm{SNR\_out} = 10 \ \mathrm{Log}_{10} \left(\frac{\text{Signal Power}}{\text{Noise Power}} \right)$$

Or SNR_out= $P_{signal}/P_{noise.}$

Wherethe power is expressed in decibel.

Artificial intelligent noise removal algorithm:

We have designed an artificial intelligent model for removal of noise from biomedical signal by using Matlab coding. The fig. 2 shows the block diagram of proposed artificial intelligent model of adaptive network based fuzzy inferencesystem(ANFIS).

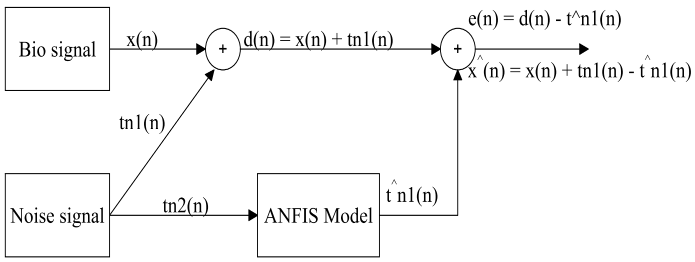

Figure 2: Block diagram of proposed ANFIS Model

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ANFIS based Noise Removal Algorithm:

Proposed model havedesigned on the basis of Sugeno architecture. The basics of Sugeno inference architecture is discussed below.

Sugeno inference architecture [18]:

In TSK or Sugeno architecture, defuzzification block of Mamdani architectureis replaced by a normalization and weighted average. The TSK architecture does not require MAX operators, but a weighted average is applied directly to regions selected by MIN operators. The TSK system is really simple because of the output weights are directly proportional to the average function values at the selected regions by MIN operators.

Sugeno and Takagi used the following architecture which is graphically represented in Fig. 3.

R1: if x is $A1$ and y is $B1$ then $z1 = p1x + q1y + r1$

R2: if x is $A2$ and y is $B2$ then $z2 = p2x + q2y + r1$

Fact: x is $x0$ and y is $y0$

Consequence: z

The firing levels of the rules are computed by

$w1 = A1(x0) \wedge B1(y0),\ w2 = A2(x0) \wedge B2(y0)$

Then the crisp control action is expressed as

$$Z_0 = \frac{w_1 z_1 + w_2 z_2}{w_1 + w_2}$$

If we have n rules in our rule-base then the crisp control action is computed as

$$Z_0 = \frac{\sum_{i=1}^{n} w_i z_i}{\sum_{i=1}^{n} w_i}$$

Where $w_i$denotes the firing level of the ith rule, i= 1, . . . , n

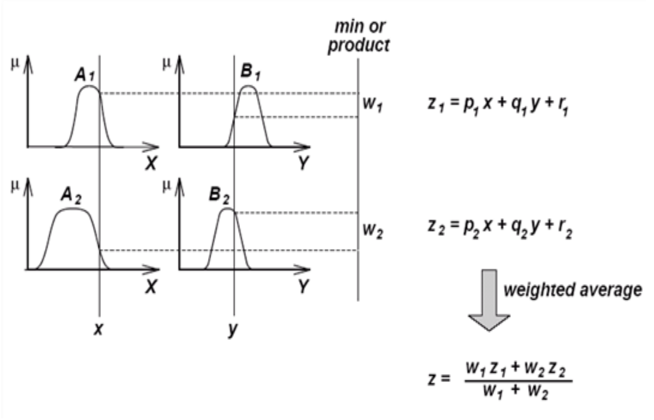

Figure 3 (a):Sugeno Fuzzy Model

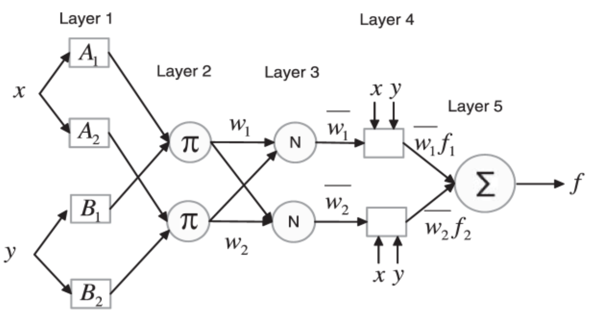

Figure 3 (b): Equivalent ANFIS architecture

For the design of model, we have selected,

Membership Functions per Input = 12

Epoch numbers = 30

No. of taps= 02

However, an epoch corresponds to the entire training set going through the entire network once. It can be useful to limit the over fitting.

In addition to this, generalized Bell Type Membership Function (MF) has been used in the network.

A generalized bell MF is specified by three parameters (a, b, c):

$$f(x; a, b, c) = \frac{1}{1 + \left| \frac{x - c}{a} \right|^{2b}},$$

where the parameter b is usually positive. If b is negative, the shape of this MF becomes an upside-down bell. However, each of these parameters has a physical meaning: c determines the centre of the corresponding membership function; a is the half width; and b (together with a) controls the slopes at the crossover points. Note that this MF is a direct generalization of the Cauchy distribution used in probability theory, so it is also referred to as the Cauchy MF. Because of their smoothness and concise notation, Gaussian and bell MFs are becoming increasingly popular for specifying fuzzy sets [58].

III. SIMULATION RESULTS

The major objective of this study was to investigate a noise removal filters. For this, simulations are carried out on ECG and EMG signals.The results are obtained on output parameter section of Matlab based GUI for removal of noise from biomedical signal. The Table 1 shows the signal to noise ratio of adaptive Filter using algorithms LMS, NLMS, NSLMS, SLMS and SSLMS for various step sizes on ECG signal 1.

Table 1: SNR_outVs Step size for adaptive filter using various algorithms

No. of taps= 2 and SNR_in= 0

Step Size	**SNR_out**				
	LMS	**NLMS**	**NSLMS**	**SLMS**	**SSLMS**
1e-7	-0.19906	26.7339	26.7339	7.97304	26.7338
1e-8	0.21109	26.7339	26.7339	24.324	26.7339
1e-9	1.23573	26.7339	26.7339	26.7018	26.7339
1e-10	10.2783	26.7339	26.7339	26.7336	26.7339
1e-11	24.5255	26.7339	26.7339	26.7339	26.7339
1e-12	26.7039	26.7339	26.7339	26.7339	26.7339
1e-13	26.7336	26.7339	26.7339	26.7339	26.7339
1e-14	26.7339	26.7339	26.7339	26.7339	26.7339
1e-15	26.7339	26.7339	26.7339	26.7339	26.7339

Table 1shows that Normalized LMS and Normalized Sign LMS algorithm performed better at a small step size also. But overall,all algorithms have good performance on step size 1e-

10, which governs the rate of convergence, speed of tracking ability.

However, use of small step size is to ensure a small steady state error. But a small step size decreases the convergence speed of the adaptive filter. However, increase in step size is to improve the convergence speed of the adaptive filter. But a large step size might cause the adaptive filter to become unstable. So we have to select optimum value of step size [57].

For this study, theANFIS based filters are examined on various biomedical signals(ECG and EMG). The SNR_outof ANFIS based filters are compared with the adaptive filters for the selected parameters;No. of Taps= 02, SNR_in= 0 and Step size= 1e-10. ANFIS based filters have tested on various ECGand EMG signals. For this, we used Generalized Bell Membership Function. The Table 2 shows the comparison of SNR_out of Adaptive and ANFIS based filters.

Table 2: Comparison of SNR_out of Adaptive and ANFIS based filters.

Algorithm	ANFIS based Filter SNR_out			Adaptive Filter SNR_out
	ECG1	ECG2	EMG	
LMS	19.5649	35.0811	22.6133	10.2783
NLMS	26.7339	35.1005	35.3044	26.7339
NSLMS	26.7339	35.1005	35.3044	26.7339
SLMS	26.7339	35.1005	35.3044	26.7336
SSLMS	26.7339	35.1005	35.3044	26.7339

From Table 2, it is inferred that SNR_out for all selected algorithms show excellent signal to noise ratio.Thus all algorithms are excellently filtered out the noise signal from thebiomedical signal.

IV. DISCUSSION

The amplitude biomedical signals are obtained in mV or in µV ranges. Thus the signals are easily affected by various noise sources result in degrading the signal. Even in the modern world of biomedical instrumentation, all possible filtering arrangements are carried out by the other researchers. But still due to randomness of noise signal, original signal get affected and this process is dynamic. So such problem demands the dynamic solution as well.

Therefore for the dynamic solution, we choose Artificial Intelligent based filtering algorithms. This has only two processes- training and testing. Training process based on subset outcomes of adaptive filtering algorithm in initial stages, which may not require in later time even on change of source input as well, called trained filter / smart filter. Such intelligent filters give the freedom of selection of signal with different SNR values; also not bother about number of parameter settings which lead one more step towards the auto filter concept.

For the simulation, we have used different ECG and EMG signals. The simulation results are carried out by measuring the performance parameters SNR_out and these results are summarized in tabular form in the Tables 1 and 2. The comparison of these two filters reveals that the ANFIS based algorithms give better results than the adaptive filter algorithms.

V. CONCLUSION

The main goal of the current study was to design artificial intelligent filters to reduce noise from the biomedical signals. The implementation of the biomedical signals on various adaptive algorithms (LMS, NLMS, NSLMS, SLMS and SSLMS) is successfully performed. The result of this study indicates that the AI (ANFIS) algorithms give better results than the adaptive filter algorithms. The AI algorithms are excellent systems to filter out the noise signal from the biomedical signal. The proposed algorithm plays an important role in noise reduction from any biomedical signals.

REFERENCES

[1] N. K. A. Chan and P. Kwong (2005); "A CMOS analog frontend IC for portable EEG/ECG monitoring applications"/ *IEEE Transactions on Circuits and Systems-I: 52(11), 2335-2347*.

[2] S. C. Douglas (1999); Digital Signal Processing Handbook/ CRC Press LCC / *Introduction to Adaptive Filters*.

[3] S. Haykin, (1999); Neural Networks:A Comprehensive Foundation/ *Prentice Hall, Upper Saddle River, NJ, pg. 63-66*

[4] S. Arar (2016); "FIR Filter Design by Windowing: Concepts and the Rectangular Window"/ https://www.allaboutcircuits.com/author/steve-arar.

[5] H. K. Gupta, R. Vijay and N. Gupta (2013) ; "Designing and Implementation of Algorithms on MATLAB for Adaptive Noise Cancellation from ECG Signal"/*International Journal of Computer Applications (0975 – 8887) Volume 71– No.5*.

[6] A. Gupta and R. Mehra(2013); "Matlab Simulation of Cordic based Adaptive Filtering for Noise Reduction using Sensors Array"/ *International Journal of Computer Applications (0975 – 8887) Volume 67– No.20*.

[7] N. Kumar and M. Nachamai(2017); Removal and Filtering Techniques used in Medical Images/*Original Journal OfComputer Science and* Noise *Technology vol. 10, No. (1): Pgs. 103-113*.

[8] T. Drumright (1998); "Adaptive Filtering" */Spring publication*.

[9] L.Sharma and R. Mehra(2016); "Adaptive Noise Cancellation using Modified Normalized Least Mean Square Algorithm"/ *International Journal of Engineering Trends and Technology (IJETT) – Volume 34 Number 5*.

[10] B.Chandrakar, O. P. Yadav and V. K. Chandra (2013); "A Survey Of Noise Removal Techniques For ECG Signals"/*International Journal of Advanced Research in Computer and Communication Engineering Vol. 2, Issue 3*.

[11] W. J. Tompkins (2000); "Biomedical Digital Signal Processing: C-Language, Examples and Laboratory Experiments for the IBM® PC"/ *Prentice Hall,UpperSaddle River, New Jersey*.

[12] R. J. George (2015); "Design of an Adaptive Filtering Algorithm for Noise Cancellation"/*International Research Journal of Engineering and Technology (IRJET), Volume: 02 Issue: 04*.

[13] D. C. Dhubkarya and A. Katara; "Comparative Performance Analysis of Adaptive Algorithms for Simulation & Hardware Implementation of an ECG Signal"/*International Journal of Electronics and Computer Science Engineering* Vol.No.1, pg.2184-2191.

ISSN: 2321-8169
89 – 94

[14] R. Sehamby and B. Singh (2016); "Noise Cancellation using Adaptive Filtering in ECG Signals: Application to Biotelemetry" */International Journal of Bio-Science and Bio-Technology Vol.8, No.2 (2016), pp.237-244*.

[15] L. Singh and K. Priya (2013); "FIR Filter Design and IIR Filter Design"/ *International Journal of Computer Science And Technology Vol. 4, Issue 1*.

[16] M.A. Razi and K. Athappilly (2005); "A comparative predictive analysis of neural networks (NNs), nonlinear regression and classification and regression tree (CART) models"/ *Expert Systems with Applications, Elsevier 65–74*.

[17] S. Silarbi, B. Abderrahmane and A. Benyettou (2014); "Adaptive Network Based Fuzzy Inference System for Speech Recognition Through Subtractive Clustering"/ *International Journal of Artificial Intelligence & Applications (IJAIA), Vol. 5, No. 6*.

[18] J. S. R. Jang (1993); "ANFIS: Adaptive Network based Fuzzy Inference System"/ *IEEE Transactions on systems Man and Cybernetics, Vol. 3 No. 23*.

[19] R.S. Khandpur (2001): "Hand Book of Biomedical Instrumentation, 2e". Mc-Graw Hill Publication, New Delhi, pg 35 Anon.(2017); http://www.electronicsandcommunications.com/2017/06/electrodes-in-biomedical-instrumentation.html .

[20] B. Yadav and S. Rana (2016); "Comparison of IIR filter and FIR Filter and their types"/*66th International Conference on Recent Innovations in Science, Engineering and Management*.

[21] A. D. Poularikas and Z. M. Ramadan (2006); "Adaptive Filter Primer with MATLAB" / *CRC press publications, Boca Raton, London, New York, pp.166*.

[22] G. S. Gawande (2012);"Performance analysis of FIR Digital Filter Design Techniques"/ *International Journal of Computing and Corporate Research, Vol. 2, Issue 1*.

[23] A. Singh (2001); "Adaptive Noise Cancellation"/ *http://www.cs.cmu.edu/~aarti/pubs/ANC.pdf* .

[24] R. L. Ortolanand et al. (2013); " Evaluation of adaptive/nonadaptive filtering and wavelet transform techniques for noise reduction in EMG mobile acquisition equipment"/*IEEE Transactions on Neural Systems and Rehabilitation Engineering Volume: 11, Issue: 1, pg.60-69*.

[25] A. Pannu (2015); "Artificial Intelligence and its Application in Different Areas"/*International Journal of Engineering and Innovative Technology (IJEIT) Volume 4, Issue 10*.

[26] D. D. Nauck (2003); "Fuzzy data analysis with NEFCLASS"/ *International Journal of Approximate Reasoning*, pp. 103–130.

[27] D. D. Nauck (1997); "Neuro Fuzzy Systems: Review and Prospects/ *European Congress Intelligent Techniques and Soft Computing (EUFIT'97)*, pp. 1044–1053.

[28] Ahmed Abdel-Aleem, M. A. El-Sharief, M. A. Hassanand M. G. El-Sebaie (2017); "Implementation of Fuzzy and Adaptive Neuro-FuzzyInference Systems in Optimization of Production Inventory Problem"/*An International Journal of Applied Mathematics & Information SciencesAppl.: Math. Inf. Sci. 11, No. 1, 289-298*.

[29] C. N. Huang C. H. Chen and H. Y. Chung (2004); "The review of applications and measurements in facial electromyography"/ *Journal of Medical and Biological Engineering, 25(1):pg.15-20*.

[30] El Falou, M. A Khalil and J. Duchene (2001); "Adaptive approach for change detection in EMG recordings"/ *Proceedings of the 23rd Annual International Conference of the IEEE, Volume: 2*.

[31] V. R. Mankarand A. A. Ghatol (2008); "Use of RBF Neural Network in EMG signal noise removal"/ *Wesas Transactions on circuits and systems, Issue 4, Volume 7, pg. 258-264.*

[32] S. N. Kale and S. V. Dudul (2009); "Intelligent Noise Removal from EMG Signal Using Focused Time-Lagged Recurrent Neural Network"/ *Applied Computational Intelligence and Soft Computing Volume 2009, Article ID 129761, 12 pages*.

[33] G. Kadam and P.C.Bhaskar (2012); "Reduction of power line interference in ECG using FIR filter"/ *International Journal Of Computational Engineering Research.*

[34] S. Poornachandra and N. Kumaravel (2008); "A novel method for the elimination of power line frequency in ECG signal using hyper shrinkage function"/*Digital Signal ProcessingELSEVIER Volume 18, Issue 2, March, Pages 116-126.*

[35] C. D. McManus, Neubert K. D. and Cramer E. (1993); "Characterization and elimination of AC noise in electrocardiograms a comparison of digital filtering methods"/ *Comput Biomed Res;26(1):48-67*.

[36] A. S. Khaing and Z. M. Naing (2011); "Quantitative Investigation of Digital Filters in Electrocardiogram with Simulated Noises"/*International Journal of Information and Electronics Engineering, Vol. 1, No. 3*.

[37] S. Bittoliya and R. P. Narwarian (2003); "Intelligent ECG signal noise removal with moving median filter using neural network"/ *International Journal of Research in Engineering &Technology Vol. 1, Issue 3, pg. 77-84*.

[38] K. Aboutabikh,I. Haidarand N. Aboukerdah (2016); "Design and implementation of a digital FIR notch filter for the ECG signals using FPGA"/*International Journal of Advanced Research in Computer and Communication Engineering Vol. 5, Issue 1*.

[39] S. Dogra and N. Sharma (2014); "Comparison of Different Techniques to Design of Filter"/ *International Journal of Computer Applications (0975 – 8887) Volume 97– No.1*.

[40] V. Walia, H. Singh and A. Sharma (2015); "ANFIS: Adaptive Neuro-Fuzzy Inference System- A Survey"/*International Journal of Computer Applications (0975 – 8887) Volume 123 – No.13*.

[41] H. M. Shifani andP. Kannan (2017); "Design and Analysis of Sub-band Coding of Speech Signal under Noisy Condition using Multirate Signal Processing"/ *International Research Journal of Engineering and Technology Volume: 04 Issue: 04*.

[42] R. Nagal, P. Kumar and P. Bansal (2017); "A Survey with Emphasis on Adaptive filter, Structure, LMS and NLMS Adaptive Algorithm for Adaptive Noise Cancellation System"/ *Journal of Engineering Science and Technology Review 10 (2) 150- 160*.

[43] D. Kriesel (2005); "Introduction, Motivation and History" /*A brief introduction to Neural Network/* Download location/ http://www.dkriesel.com/en/science/neural_networks - *Pg.8-12*

[44] B. Macukow; "Neural Networks:State of Art, Brief History, Basic Models and

Architecture"/http://www.mini.pw.edu.pl/~macukow/wspolne/selection.pdf

[45] B. C. Bangal (2009); "Artificial Neural Network"/ *http://shodhganga.inflibnet.ac.in/bitstream/10603/48/6/chaper%204_c%20b%20bangal.pdf*

[46] B. Kosko (1992); *Neural Network for Signal Processing*, Prentice Hall, Englewood Cliffs, NJ, pg. 1-36

[47] T. Agarwal; *https://www.elprocus.com/artificial-neural-networks-ann-and-their-types/*

[48] Anon. (2015); https://www.tutorialspoint.com/artificial_intelligence/artificial_intelligence_tutorial.pdf.

[49] R. A. Gayakwad (1999);"Op-Amps and Linear Integrated Circuits (3e)"*/ Prentice Hall of India, pg. 290-293.*

[50] *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering,Vol. 4, Issue 3.* G.Narula (2017); [

[51] https://www.techemergence.com/everyday-examples-of-ai/

[52] G. Sathiyabama, G.Vinudevi, Abhilashini.R and P.Indhupriya (2015); "A Survey on Instrumentation Amplifiers used for Biomedical Application" / [

[53] K. P. Keshab. (1999); "VLSI Digital Signal Processing Systems Design and Implementation"/ *A Wiley- Interscience Publication.*

[54] R. G. Lyons (2011); "Understanding Digital Signal Processing, 3e"/ *Prentice hall Publications*.

[55] R. A. Asghar and Abu Zar; "Matlab simulator for adaptive filters"/*http://www.diva-portal.se/smash/get/diva2:829400/FULLTEXT01.pdf*

[56] Zadeh L. A.; "Fuzzy Sets", *Elsevier Journal of Information and Control, Vol. 8, 1965, pp. 338-353.*

[57] J. Lee, J. W. Chen and H. C. Huang (2009); "Performance Comparison of Variable Step-Size NLMS Algorithms"/ *Proceedings of the World Congress on Engineering and Computer Science 2009 Vol I.WCECS2009, San Francisco, USA.*

[58] Anon.; "Fuzzy Logic Membership Function"/ *http://researchhubs.com/post/engineering/fuzzy-system/fuzzy-membership-function.html*