Enhancement of Noise Corrupted ECG Beats Using Elman Artificial Neural Network: An Experimental Approach.

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Abstract— **ECG signal is a diagnostic approach in ascertaining the working of human heart. Physicians advise to get a record of ECG trace before any preliminary investigation once the symptomatic signs come up. The record is utilized for diagnosis and interpretations and locating the exact spot or area causing the disturbance which could be the pacing of the heart or heart rate variation. Noise sources corrupt the signal while it is captured. Pressure on electrodes and power line interference are the main sources of artifacts in ECG graph. These noise signals corrupt ECG and need to be removed in order to enhance ECG signal analysis and it's interpretation. The objective of this study is to enhance ECG signal quality using Elman ANN filter using Matlab approach.**

Keywords— **Artifacts, Noise elimination, Template**

I. INTRODUCTION

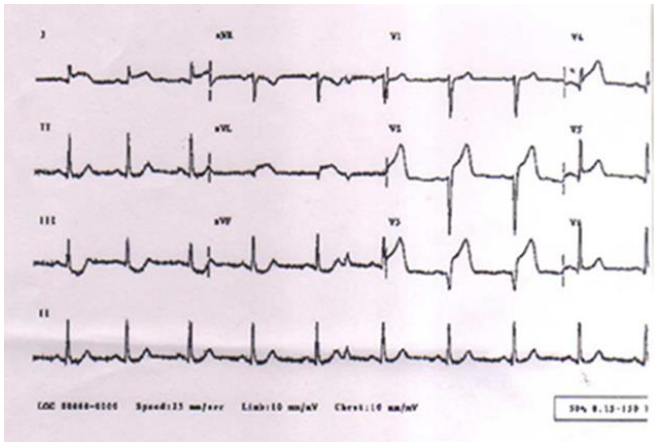
ECG is the graphical strip on a paper projecting the electrical activity of the heart. It is used to get the first hand information about the working of the heart, diagnosis of the problem and finally interpretations by the physicians leading to the type of treatment. Information in an ECG is in terms of peaks and time duration of various components. [1] Unwanted frequency components present in the signal due to reasons other than the cardiac reasons degrade the performance of the system.[2] It is not easy to filter noise during capturing the signal though a lot of improvements in the manufacturing of the equipment takes place to improve the same. ECG enhancement occurs by noise elimination. ECG signal enhancement is necessary for obtaining good quality ECG and hence for accurate diagnosis.[3] Quality improvement in the ECG signal is reported by different techniques like maximally decimated filter banks.[4], averaging techniques, wavelet transform, singular wave decomposition, independent component analysis, adaptive filtering [5] etc. A computer based noise removal approach using Elman ANN has been presented in this work. The program has been written using MATLAB. The ECG information in terms of beats comprising peak values of P, Q, R, S, T are extracted from the waveform of a 63 year old female patient having 10 hours of chest pain and sweating. Signal information is non linear and non stationary and for different illnesses the patterns are dissimilar which makes the task difficult to recognize the patterns and putting forward the interpretation.

II. ARTIFICIAL NEURAL NETWORK

ANNs analyze the patterns without storing patterns or templates. They are capable of learning these non linear patterns. Design of the ANN needs examples to learn the spatiotemporal or non linear signal. Number of examples depends upon the size of the network that are required for training. ANNs are robust to recognize these patterns.

Fig. 1 A 63years old woman with 10 hours of chest pain and sweating.

ANNs are widely used for detecting arrhythmias as they are



non linear processing units. They have a mode of learning by reading similar patterns.

III. DATA SOURCE

Data source: ECG data loaded from the http://www.sh.isuhsc.edu/fammed/OutpatientManual/EKG/postlat.html) manual.

The corrupted data is fed as an input to the Elman ANN filter. This filter uses back propagation approach for modification of the error at the output. After 1,000 iterations the filter gives the response with production of signal at the output with enhanced SNR.

The trace comprises of a number of beats. The P,Q,R,S,T amplitudes of various beats in the lead II are extracted by means of AutoCAD software as the digital equivalent is not available and there is requirement of the digital data for training a network. Noise vector is added with the signal source keeping in mind the corruption of the signal during it's pick up.

IV. ECG MODELING

As the signal is picked up surrounding environment plays a significant role to modify the real patient signal. This modified signal needs to be addressed by noise removal measures. This noisy signal is passed through the filter used in the study. Noise removal from the signal improves the quality of the signal as claimed by SNR enhancement in the table 1 which would further help in taking the correct decision for the type of treatment. Thus diagnosis would strengthen the medical aid to the patients even in rural areas where the digitization of data may hamper in reaching the correct diagnosis. The Elman filter is trained to filter the signal and learn the patterns which are different beats in this work for a particular illness. A random signal generated is added with the signal which is fed to the input of the filter. The random signal may be different from the noise picked up during recording of the signal thus generating deviations in the results. The spectrum of the output might not overlap with that of noise corrupted signal. Noise has a tendency to add up with the data and generate noisy patterns. Data acquired in this technique is added with a noise source. The noise signal is fixed signal shown at the top of Table 1 and the measurements are taken in millimeters. Modeling on ECG record is like modeling heart beats with few characteristic wave forms.[6] The first key point in ECG analysis is to detect Q R S wave and then other parts of the wave using manual annotation method and statistical techniques. These signal components contain information for detection of transient arrhythmias [7]. Arrhythmias are nothing but abnormalities in the ECG patterns which could be pacing of the heart or low heart rate. Arrhythmic symptoms may not be present all the time but manifest at different intervals [8]. Fig. 2 shows the plot of the data obtained in the interpretation of the process. In this work Elman ANN based code has been used to filter spatiotemporal or non linear signal.

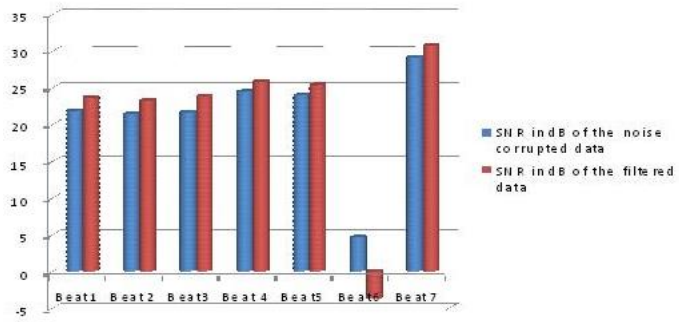


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Fig. 2 Analysis of the extracted information

X(n) ; signal to be filtered or filtered signal

n=1:5 ; n is five element vector

Summ =sum(X(n)-max(X(n))).^2
; Summ is the variable created for calculations

PRD = sqrt(Summ /sum (X(n))^2)*100
; percentage root mean square difference

SNR = -20*log(0.01*PRD)
;signal to noise ratio

y= db(SNR)dB ;signal to noise ratio in dB

V. RELATED WORK

There are different methods to reduce noise in the ECG signal and make the data suitable for analysis:

Cubic Spline interpolation based filter helps to remove base line drift and artifacts [9]. Power line disturbances is a major source of these artifacts. This removal of base line drift is the first essential step in the signal enhancement in the future work.

Weighted moving average filter reduces noise from the data that increase the reliability of the data [10]. Reliability of the data is necessary in case of bioelectrical signal because they describe the behavior and working of the system of an individual. Small deviations in the data may be misleading in the course of the treatment.

Averaging technique needs alignment of the identical portion of the signal in the data before the processing and then averaging procedure is applied to obtain the filtered signal.

Weighted moving average filter reduces noise from the data that increase the reliability of the data [11]. A neuro fuzzy approach was used for ECG beat classification. Lyapunov exponents are the features derived from ECG and neuro fuzzy model does the classification. An accuracy of 96.39% was achieved in the study [12]. Various studies indicate an accuracy of more than 95% in pattern recognition using ANNs.

In this work denoising method was used for signal recovery from the signal that contained white additive Gaussian noise. Wavelet based noise removal technique was used and thresh holding concept was applied that showed better performance than existing threshold technique.[13] Several methods of ANN have been applied for pattern recognition and noise removal. ANNs are used because they are specially designed to process the non stationary and spatiotemporal signals. They learn by examples and need not store the patterns. Neural networks obtain reasonable accuracy in filtering out the signal of interest.[14]

The neural network utilizes adaptive function for detecting arrhythmias. The network is a three layer network and an accuracy of 99.92% was reported.[15]

VI. Methodology

Methodology involves the use of AutoCAD and Matlab software hybrid approach on a hp laptop processor with speed of 1.80 GHz. AutoCAD was used in lieu of the non availability of the digital traces of the ECG of the records under study. The analog data recorded and used in the study is graphical in nature and thus extraction procedure is required in this work. The extraction of the parameters was made using AutoCAD and the filtering action was performed with the help of Matlab software on the software Celeron processor. The following steps have been adopted in this work:

1 A pattern is down loaded that is graphical in nature from the manual. Beat parameters are extracted from ECG trace from lead II. Noise is added to the extracted parameters.
2 Elman filter was used and was trained with the beats data to achieve the target.
3 Complex signal passes through non linear circuit to generate distorted signal which can be a signal from ECG machine.
4 Distorted information mixed with noisy signal is fed as an input to the Elman filter.
5 Signal is processed with one input node, hidden layer with ten neurons activated with Tansigmoid activation function and generating output at the output node with Purelin activation function.
6 Error at output is back propagated using back propagation and the input is again fed to the network.
7 Output generated at the output neurons is compared with noise free signal which is target.
8 The error is calculated using the formulae, Error = (Output (at output neurons) - target). The error is reduced to a minimum. An error of the order of .001% is achieved in the study. Learning rate used in the network is 0.007.
9 Enhancement of the ECG signal at the output of the filter is shown in Table 1 and plot of the noise comparisons are presented in Fig. 2

TABLE 1:
SHOWS THE SNR VALUES FOR THE CORRUPTED, FILTERED AND IMPROVEMENT in SIGNAL in dB

Noise Beat [0.26 0.45 0.3 0.25 0.6]

S.No	Beat	Noise corrupted signal	Target Achieved	SNR(dB) Of noise Corrupted beats	SNR(dB) With Elman ANN filtered output	SNR improvement in dB
1	[2.9 0.7 8.2 -1.7 2.9]	[3.16 1.15 8.5 -1.45 3.5]	[2.8975 0.7331 8.2080 -1.7012 2.9109]	21.8767	23.6739	1.7972
2	[2.3 1 8.6 -0.8 2.9]	[2.56 1.45 8.9 -0.55 3.5]	[2.3121 1.0067 8.6051 -0.7875 2.8771]	21.4524	23.2721	1.8197
3	[2.1 0.9 7 -1.7 2.7]	[2.36 1.35 7.3 -1.45 3.3]	[2.0968 0.8930 7.0005 -1.6906 2.6963]	21.7104	23.8713	2.1609
4	[1.3 1 9.4 -1.5 2.6]	[1.56 1.45 9.7 -1.25 3.2]	[1.2934 1.0347 9.3937 -1.5194 2.6038]	24.4701	25.8557	1.3856
5	[1.4 0.7 9.4 -1.1 2.9]	[1.66 1.15 9.7 -0.85 3.5]	[1.3945 0.7038 9.4005 -1.1025 2.8993]	23.9522	25.3938	1.4416
6	[1.6 0 8.5 3.1 8.4]	[1.86 0.45 8.8 3.35 9]	[1.6094 -0.0130 8.5068 3.1141 8.3943]	4.6482	-3.7658	8.414
7	[1.5 -6.3 7.9 1.3 1.6]	[1.76 -5.85 8.2 1.55 2.2]	[1.4788 -6.2998 7.9039 1.2993 1.6087]	29.1815	30.7420	1.5605

VII. Process Chart

The steps involved in the process are shown in the flow chart of the process, Fig. 3

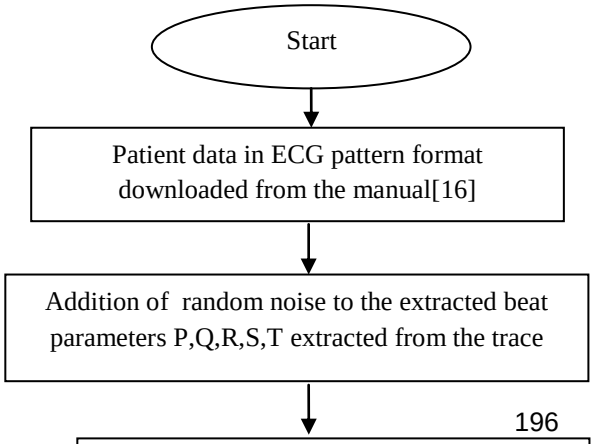

Fig 3. Flow chart of the process

VIII. RESULT AND DISCUSSION

The results obtained in terms of signal to noise ratio in dB are presented in the Table 1 which indicates a significant enhancement in the signal with Elman ANN filter in six beats out of seven beats. The values of weights were fixed in the Elman ANN when the network showed an error of 0.001%. For any filtering action the values of coefficients are unique. Likewise the weights at which the results are obtained are [-0.0401 -1.3328 0.6394 0.1071 -0.9033 0.5559 -1.5679 1.7786 -1.1938 -1.1039]. The learning rate of 0.007, number of epochs 100 and a goal of 1e-5 is selected in the analysis.

Noise filtration will definitely add to the development and use of new methods for designing ECG equipments which is a need for the constant development of the ECG design procedures and that leads to promote the health status of the patients worldwide.

Further a lot of work can be done in filtering the signal using soft computing technique which would strengthen the design processes of ECG machine. Soft computing methods further can be used by hybridizing them with some optimization technique like GA or BFO etc or by designing other filters and comparing the results with this study

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