International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-2 Issue-3, February 2013

Adaptive Filtering and Compression of Bio-Medical Signals Using Neural Networks

Kalyan Chatterjee, Mandavi, Prasannjit, Nilotpal Mrinal, S.Dasgupta

Abstract*—biomedical signals are often contaminated by noise. Thus, noise removal and subsequently their lossless compression is also very necessary. This paper presents an adaptive filtering technique for removing noise from ECG signal using the Recursive Least Square (RLC) method. Twelve significant features are extracted from an echocardiogram (ECG) dataset. After carrying out noise cancellation followed by Recursive Least Square method filtered, ECG signal is obtained. Moreover we have also compressed the ECG signals. The filtered signals are used as input to the artificial neural network. Finally these samples which are used in the database are trained and tested using the Back Propagation Algorithm. The compression ratio is observed to be 0.9745583.It is further observed that input signals are same as the supervised signals used in the network. This paper presents experimental results which demonstrates the usefulness of adaptive filtering and data compression in several bio-medical applications.

***KEYWORD*—Adaptive filtering, Data compression, back propagation, Recursive least square method.**

I. INTRODUCTION

The electrocardiogram (ECG) was introduced into clinical practice more than 100 years ago by Einthoven. It provides representation of the electrical activity of the heart over time and is the most useful indicator of cardiac functions. ECG signals which are extracted are often contaminated with noise which arises from power line transmission, movement of recording electrode or due to interference of signals. In order to get a high resolution of signals, these are needed to be filtered. Due to superior convergence properties, Recursive Least Square method is used in adaptive filtering. Also, in an average sized hospital, many tera-bytes of data are generated every year, almost all of which has to be kept and archived. Archiving this large amount of data in the computer memory is very difficult without any compression. As these data are vital in nature so, better compression ratio with higher efficiency is needed. In this paper, we have used back propagation for data compression. The test result at each stage are consistent and reliable and prove beyond doubt that the composite method can be used for efficient data compression and adaptive filtering of ECG signals in many real time applications.

Manuscript published on 28 February 2013.
***** Correspondence Author (s)
Kalyan Chatterjee, computer science engineering, Bengal college of engineering & technology, Durgapur, India.
Mandavi, information technology, Bengal college of engineering & technology, Durgapur, India.
Prasannjit, information technology, Bengal college of engineering & technology, Durgapur, India.
Nilotpal Mrinal, information technology, Bengal college of engineering & technology, Durgapur, India.
S.Dasgupta, computer science engineering, Bengal college of engineering & technology, Durgapur, India.

II. ADAPTIVE FILTERING

Due to continuous changing of noise over a time period and overlapping of frequencies of noise and signal, adaptive filtering is going to become a necessity. They are proving to be a powerful resource for real time applications when there is no time for statistical estimation. The ability of adaptive filters to operate satisfactorily in unknown and possibly time-varying environments without user intervention and improving their performance during operation by learning statistical characteristics from current signal observations has made them more efficient.

III. RECURSIVE LEAST SQUARE ALGORITHM

There are many algorithms which are used now-a-days. But, due to superior convergence properties and calculation of result in real time we have used RLC method in this paper. The equations used in this method are:-

$$\mathbf{W}_k = \mathbf{W}_{k-1} + \mathbf{G}_k e_k$$

$$\mathbf{G}_k = \frac{\mathbf{P}_{k-1}\mathbf{x}(k)}{\alpha_k}$$

$$e_k = y_k - \mathbf{x}^T(k)\mathbf{W}_{k-1}$$

$$\alpha_k = \gamma + \mathbf{x}^T(k)\mathbf{P}_{k-1}\mathbf{x}(k)$$

Where γ =forgetting factor

μ =learning parameter

$\mathbf{P}_k$ =recursive way to compute the inverse matrix

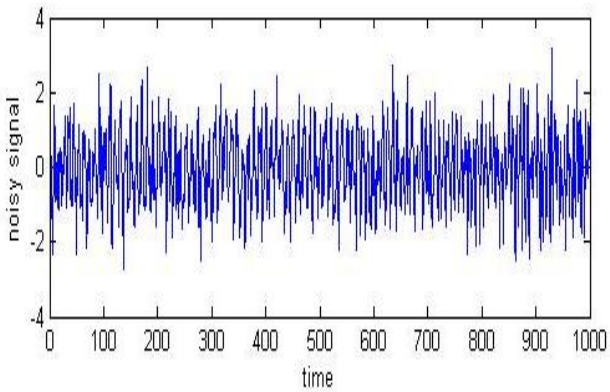

Fig1. sample signal contaminated with noise

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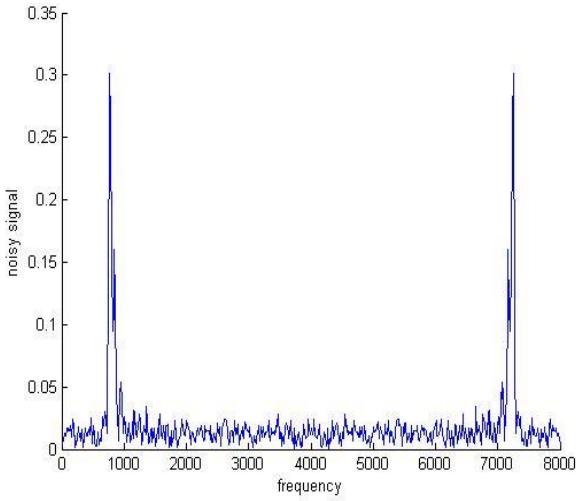

Fig. 2. frequency of sample signal mixed with noise

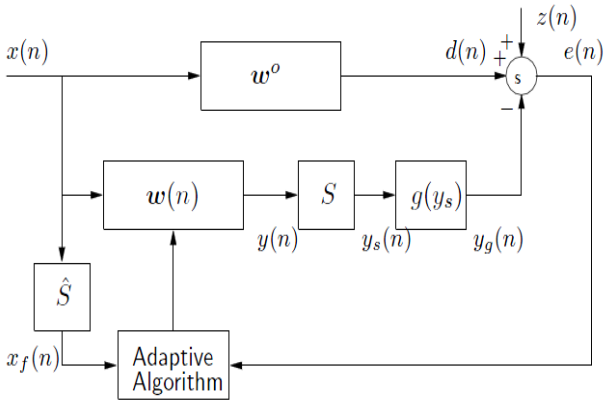

Fig.3. block diagram of active noise cancelation

IV. DATA COMPRESSION

Compression is used just about everywhere. All the images we get on the web are compressed, typically in the JPEG or GIF formats, most modems use compression and several file systems automatically compress files when stored, and the rest of us do it by hand. Many compression algorithms exist which have shown some success in electrocardiogram compression; however, algorithms that produce better compression ratios and less loss of data in the reconstructed data are needed. Compression rate measures how much the signal can be compressed from the original one. Compression methods used can be lossless and lossy.

A. Lossless compression

Lossless compression implies the original data is not changed permanently during compression. After decompression the original data can be retrieved. The advantage of lossless compression is that the original data stays intact without degradation of quality and can be reused. The disadvantage is that the compression achieved is not very high.

B. Lossy compression

In lossy compression technique, parts of the original data are discarded permanently to reduce file. After decompression the original data cannot be recovered this leads the degradation of quality.

Fig.4. lossless compression

Fig.5.lossy compression

V. DATA COMPRESSION TECHNIQUES

Data compression techniques have been classified in a broad spectrum of communication areas such as speech, image and telemetry transmission. One of the techniques of compression of bio-medical signals is listed as follows:

A. Linear Predictive Coding (LPC)

Linear predictive coding (LPC) is defined as a digital method for encoding an analog signal in which a particular value is predicted by a linear function of the past values of the signal. The most important aspect of LPC is the linear predictive filter which allows the value of the next sample to be determined by a linear combination of previous samples. But there is information loss in this technique, thus, it comes under lossy compression.

VI. DATA COMPRESSION USING BACK PROPAGATION

Back propagation is a systematic method for training multilayer artificial neural networks.It has a mathematical foundation that is strong if not highly practical.It is a multi-layer forward network using delta learning rule,commonly known as back propagation rule.

The training algorithm of back propagation involves four stages:-

i) Initialization of weights.
ii) Feed forward
iii) Back propagation of errors.
iv) Updating of weights and biases

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VII. LINEAR SCALING

The given dataset are in analog form and need to be converted to digital form. Scaling has the advantage of mapping the desired range of variable i.e. ranges between minimum and maximum range of network input. The conversions are based on certain ranges, which are defined for each attribute. There are total twelve attributes. The numerical attributes are in analog form scaled in the range between 0 and 1.The following formulae has been used for linear scaling:-

Delta = $X_{max} - X_{min}$

Y = Intercept C = $(X-X_{min})/Delta$

Slope (m) = 1/Delta

So we can calculate Y for a given X,

Y = mX + C

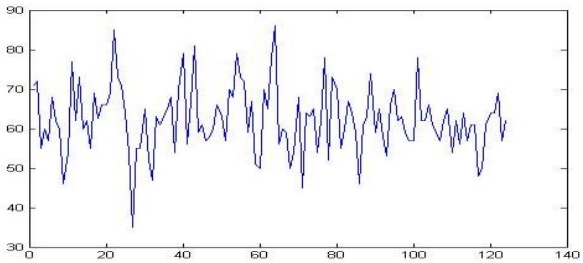

Fig.6. Graph representing one of the attributes of sample analog data

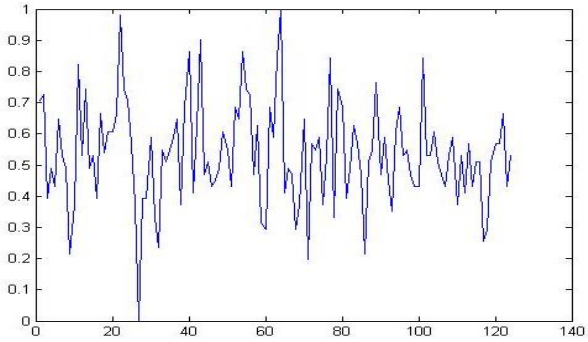

Fig.7. Graph representing linear scaled data

VIII. BIPOLAR CODING

The numerical attributes are in analog form scaled in the range between 0 and 1. Thus for converting into binary (digital) form, we assign a discrete value of "0" to the attribute value of less than or equal to "0.5".

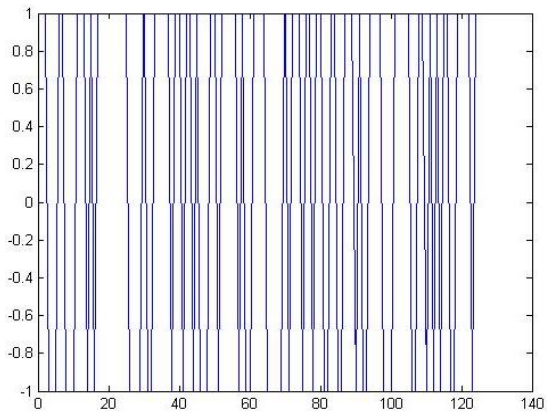

FIG.8. Bi-polar coding

IX. RESULTS

A. FILTERED SIGNAL

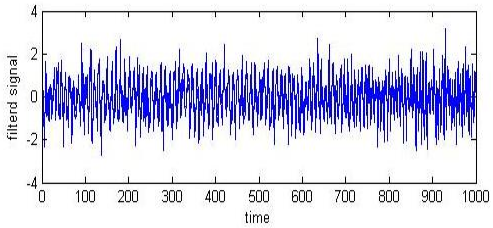

Fig.9.filtered signal

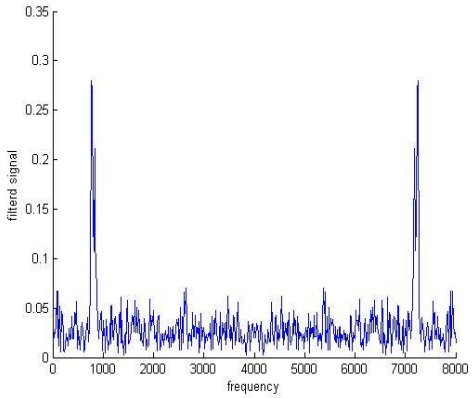

Fig.10. frequency of filtered signal

B. SELECTION OF LEARNING RATE (A):

Number of epochs = 100

TABLE1: Selection of learning rate

Serial Number	Alpha (α)	Mean Squared Error ($0.5\ S(t_k - y_k)^2$)
1	0.9	1.9481
2	0.8	1.7823
3	0.7	0.5663
4	0.6	0.5621
5	0.5	0.54239
6	0.4	0.5300
7	0.3	0.51221
8	0.2	0.4654
9	0.1	0.3211
10	0.05	0.3760
11	0.005	0.3221

C. TEST RESULTS FOR DIGITAL DATA

Learning Rate (α) = 0.05

Momentum Parameter (μ) = 0.1

Compression Ratio = 0.974583

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TABLE2: Test Results for Digital Data

S.no.	Training Data	Testing Data	Simulation Time (min)	Efficiency (%)
1	20%	80%	4.15	72.14
2	40%	60%	14.8	75.43
3	60%	40%	30.79	82.32
4	80%	20%	44.87	85.69
5	95%	5%	49.07	89.57

D. ***TEST RESULT FOR ANALOG DATA***

Learning Rate (α) = 0.05

Momentum Parameter (μ) = 0.1

Compression Ratio = 0.974583

TABLE3: Test Results for Analog Data

S.no.	Training Data	Testing Data	Simulation Time (min)	Efficiency (%)
1	20%	80%	3.95	79.55
2	40%	60%	14.78	81.67
3	60%	40%	34.89	83.69
4	80%	20%	47.12	92.17
5	95%	5%	58.07	99.5

X. CONCLUSION

Simulation of adaptive filtering and back propagation algorithm in this paper has achieved the objective of noise cancellation and data compression of ECG signals based on the given data set. This paper is simulated for the echocardiogram dataset also, it must be noted that recursive least square method has been used for adaptive filtering of ECG signals and linear scaling as well as bi-polar coding is used for digitizing the filtered ECG signals. After all these processes, back propagation is applied in order to compress the signals and 99.5% of accuracy is observed. Hence it can be concluded that after adaptive filtering, back propagation method is best suited for data compression algorithm which proves out to be lossless compression.

XI. ACKNOWLEDGMENT

The authors are thankful to IJEAT for giving them the opportunity to present their research work.

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PRASANNJIT, B.Tech 3rd year student, Department of Information Technology, Bengal College of Engineering and Technology.

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MANDAVI, B.Tech 3rd year student, Department of Information Technology, Bengal College of Engineering and Technology.

NILOTPAL MRINAL, B.Tech 3rd year student, Department of Information Technology, Bengal College of Engineering and Technology.

KALYAN CHATTERJEE , Currently, working as an Assistant Professor, Department of Computer Science Engineering, Bengal College of Engineering and Technology, Durgapur.

Dr. S.DASGUPTA, Currently working as Professor and Head of Department, Computer Science Engineering department, Bengal College of Engineering and Technology, Durgapur. He was also an Ex-scientist at CMERI, Durgapur.

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