Lossless Compression of ECG Signal and Transmission

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***Abstract*—Compression and transmission of signals plays a vital role in the modern medical field. Signals, when collected for a long period of time, size will become larger. ECG (Electro Cardio Graph) signals require large amount of disk storage space. The size of ECG can be effectively reduced by signal compression, which results in efficient utilization of file size by reducing the size of the signal and without compromising the quality of the signal. The compressed signals can be transmitted at a faster rate over a medium. Different compression algorithms have been devised for the compression. In this experiment the neural network predictor is used to predict the ECG signals and they are compressed by using Huffman coding. Huffman coding reduces the size of the signal losslessly and makes the signal error free. The compressed signal is stored at the database. From the database signals can be transmitted to the doctor for the continuous analysis of the ECG with the help of an android application. When doctor selects a patient, the request is being transmitted through the web server to the database. From the database the ECG wave of the particular patient is transmitted to the android application. Thus the doctor could view the ECG waveform and diagnose the patient even from a distant place.**

Keywords – ECG signal; artificial neural networks ; lossless compression; huffman coding; andriod application

I. INTRODUCTION

The human heart holds a special place among bodily organs. It pumps blood through the whole body over 100,000 times daily [1]. The biopotentials generated by the muscles of the heart result in the electrocardiogram (ECG). Fig. 1, shows a typical ECG as it appears when recorded from the surface of the body.

To facilitate analysis, the horizontal segment of this waveform preceding the P wave represents activation of atria, which are the chambers of the heart that receive blood from the body. The QRS complex is the combined result of the repolarization of the atria and depolarization of the ventricles, occurs almost simultaneously. This represents activation of left ventricle, which sends oxygen-rich blood to the body, and the right ventricle, which ends oxygen-deficient blood to the lungs. The T wave is the wave of ventricular repolarization. The shape and polarity of each of these features which vary with the location of the measuring electrodes with respect to the heart, and a cardiologist normally bases his diagnosis on readings taken from several electrode locations. Thus it is the features of ECG that uses to analyze the health of the heart and note various disorders [2].

ECG signals are recorded by applying electrodes to various locations on the body surface. An ECG signal must consist of 3 individual leads, each recording 10 bits per sample, and 500 samples per second. Some ECG signals may require 12 leads, 11 bits per second, 1000 samples per second and last 24 hours. ECG signals are stored for both storage and diagnostic purposes.

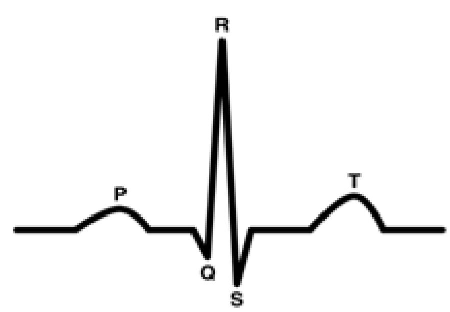

Fig. 1. An ECG waveform

When an ECG signal is converted to digital format, a single ECG record requires a total of 1.36 gigabytes of computer storage. When 10 million ECG's annually required for the comparison, the storage and transmission of such bulk data is difficult. That is why effective compression of ECG is required mostly [3].

Furthermore compression of ECG signal is needed for better transmission of the data. There are certain amounts of sample points in ECG signal which are redundant and replaceable. ECG data compression is achieved by eliminating such redundant data sample points [4]. Compression is used to reduce the volume of information to be stored into storages or to reduce the communication bandwidth required for its transmission over the networks.

Data compression techniques are adopted by the effective measures of Compression Ratio (CR), a ratio of size of compressed data to original data; execution time, the computer processing time required for the compression and reconstruction of ECG data and measure of error loss.

The compression can also be done by the prediction of incoming data. Neural networks and adaptive Fourier coefficients will result in higher compression ratios. Artificial Neural Networks (ANN) is electronic models based on biological neural structures [5].

ANN's have greater capacity in predictive modeling. Neural network drives its computing power through, first its massively parallel distributed structure and, second, its ability to learn and therefore generalize. Generalization refers to the neural network producing reasonable outputs for inputs not encountered during training (learning). These two information processing capabilities make it possible for neural network to solve complex problems that are currently intractable [6]. Thus by combining both these methods of statistical encoding and Huffman coding the ECG signal can be compressed [7].

A dictionary is used for ease of the transmission. For each of the transmitting signal, a dictionary is being created at the Huffman Encoder.

The data transmission helps in sending and receiving the data. It can be done in a number of ways. A wireless data transmission in which microwave links are used to send and receive signals on frequencies in the gigahertz range can be used for the transmission of the signal. A mobile operating system acts as an interface that allows smart phones, tablet and other devices to run applications and programs.

II. PERFORMANCE INDICATORS

In order to measure and quantify the performance of compression technique, some performance indicators are used as follows:

- *Compression Ratio (CR)*

Compression ratio defines the ratio of number of bits required to represent original image to the number of bits required to represent compressed image. As the compression ratio increases, the quality is compromised. Lossy compression techniques have higher compression ratio than lossless compression techniques [8].

$$\text{CR} = \frac{\text{bits required to represent original image}}{\text{bits required to represent compressed image}} \quad (1)$$

- *Mean Square Error (MSE)*

MSE is the measure of error between the original signal and the compressed signal. Mean Square Error is the cumulative squared error between the compressed signal and the original signal. For the lesser distortion and high output quality, the MSE must be as low as possible [9].

$$\text{MSE}= \frac{1}{2}\sum(original\ signal - compressed\ signal)^2 \quad (2)$$

- *Percent mean Square difference (PRD)*

It is the measure of error loss and is calculated as follows [10]

$$PRD = \left\{\sqrt{\frac{original\ signal}{compressed\ signal}}\right\} 100\ \% \quad (3)$$

III. DATA COMPRESSION AND TRANSMISSION METHOD

The block diagram of lossless data compression and transmission method can be seen in the Fig. 2. About 1000 samples from the MIT-BIH Arrhythmia database is selected and given to the Neural Network Predictor for training. The predictor that is implemented at the method above is Back-Propagated networks (BP). The network topology is constrained to be feed forward. The input layer collects the signal from the external world, connections are allowed from the input layer to the hidden layers. The hidden layer has

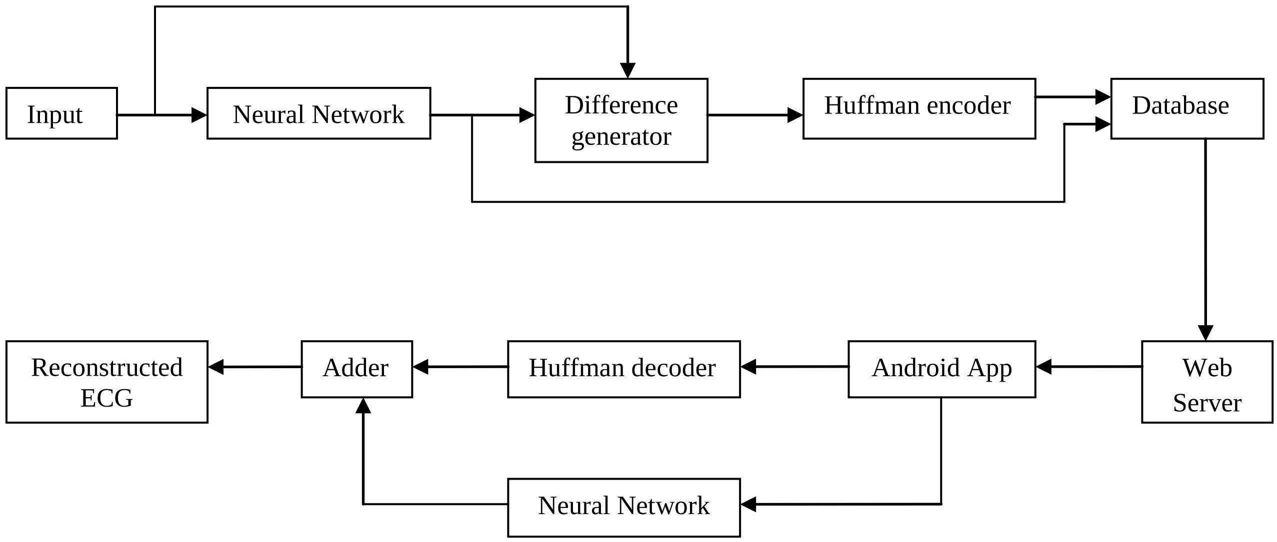

Fig. 2. Block Diagram of lossless Data Compression and Transmission Method

no inputs or outputs to the external world, and is considered to be categorizers or feature detectors of input signals. Fig. 3, shows the input and output of a single hidden layer neuron. Here the network consists of one hidden layer with 71 neurons. They learns to recode (or to provide a representation for) the inputs and send to the output layer which is the collector of the features detected and producer of the response.

The architecture is more powerful than single-layer networks. Learning in a neural network is called training. The procedure used to perform the learning process is called learning algorithm, the function is to modify synaptic weights and biases of the neural network in an orderly fashion to attain a desired design objective. From the difference between the desired response and the actual response, the error is determined and a portion of it is propagated backward through the network. At each neuron in the network the error is used to adjust the weights and threshold values of the neuron, so that the next time, the error in the network response will be less for the same inputs. The network is trained for 500 times. During training the weights and biases of the network are iteratively adjusted according to its error [11].

The output from the neural network is rounded off and given to a difference generator. The difference generator generates a residue of the input ECG and neural network. This residue is fed to the Huffman encoder. Huffman encoder encodes the signal to Huffman coded format to minimum bit representations. Huffman Code assigns shorter encodings to elements with high frequency. Elements with the highest frequency get assigned the shortest bit length code. The key to decompressing Huffman code is a Huffman tree. A Huffman dictionary is created here which includes the probability with which the source produces each symbol in its alphabet. This increases the compression rate of the signal. The compressed data from the Huffman encoder and the output from the neural network are stored at the database.

The android application acts as the receiver end. The signal is transmitted to an android based mobile phone, with the help of a web server. The android is an open mobile phone platform that was developed by Google. It is a Linux-based operating system. Android is open source and user interface in based on direct manipulation using touch inputs. Applications are developed in the Java language using the Android software development kit (SDK). The android application acts as the receiver end. The signal is transmitted to an android based mobile phone, with the help of a web server. The android is an open mobile phone platform that was developed by Google. It is a Linux-based operating system. Android is open source and user interface in based on direct manipulation using touch inputs. An Android application (android app) can be said as the software application running on the Android

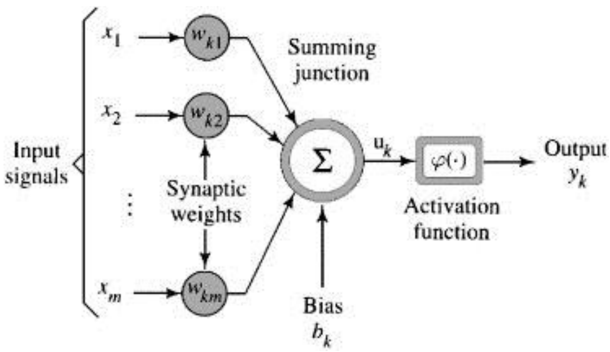

Fig. 3. Input and output of single hidden layer neuron

platform. In the android application with the help of Huffman dictionary the Huffman decoder decodes the signal. An identical training and prediction is done with the help of output from the neural network and the weight and biases are adjusted. The original signal is reconstructed at the adder circuit with the output from the Huffman decoder and neural network. The doctor can login to the application with a login Id and password. From the available list of patients doctor can select a patient. The ECG of the selected patient is fetched and doctor can analyze this signal and diagnose the patient.

IV. RESULT AND DISCUSSION

Data compression can be done in a number of ways. The input ECG signal is fed to the neural network predictor to build the weights and biases. In the neural network predictor the training of the signals are being taken place when the program is run. Input and the target output should be given to the network for training. Once the goal is reached the predicted output of the network is available. The training state of the neural network can be seen in the Fig. 4.

The difference between the original and the predicted signal is obtained. This residue is given to the Huffman encoder. Huffman encoder coverts the residue to Huffman codes, with shorter codes for frequently occurring signals. A Huffman dictionary is created here for this purpose. The Huffman encoded output and neural network output are saved at the database. With the help of web server the encoded ECG can be transmitted to the android ECG application. The data is decoded here to the original format at the adder with the help of Huffman dictionary and neural network. Thus the original signals are reconstructed. In the Android ECG application the doctor could view the ECG waveforms of the patients. The doctor can select the waveform of a patient and diagnose the patient.

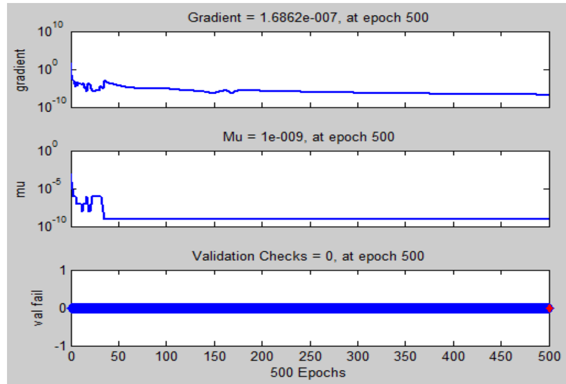

Fig. 4. Training state of neural network

The input ECG and the Recovered ECG are given in the Fig. 5. Here the input ECG is a normal ECG signal. At the time of heart abnormalities there will be variations in the ECG. When an abnormal ECG signal is inputted the output obtained is given in the Fig. 6.

About 1000 samples from the MIT Database are used. When the incoming data is the same with the target data we got the compression ratio of 0.1110, mean square error as 0.1185 and percent mean square difference of 0.0118. When there is variation in the input data (i.e. at the time of heart abnormalities) the compression ratio as well as the other performance indicator values varies. The variation in the values obtained when using different input signals are tabulated under the Table 1.

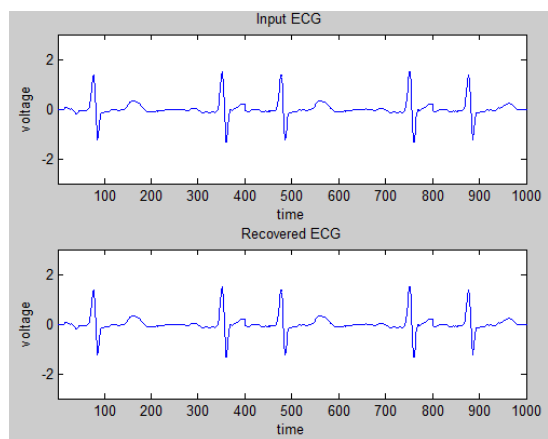

Fig. 5. Normal ECG input and the Recovered ECG

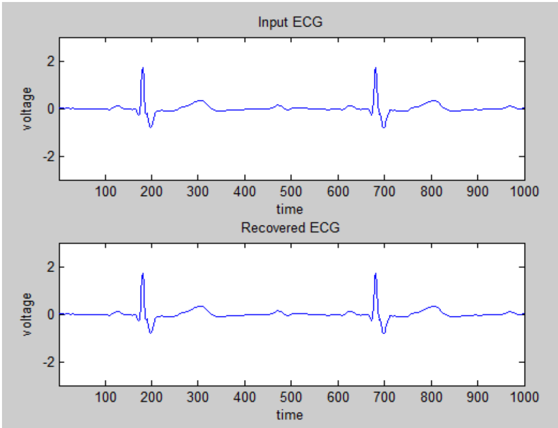

Fig. 6. Abnormal ECG input and the Recovered ECG

TABLE 1. PERFORMANCE INDICATING VALUES OF DIFFERENT WAVEFORMS.

	CR	MSE	PRD
ECG 1	0.1110	0.1185	0.0118
ECG 2	0.1083	0.1281	0.0128
ECG 3	0.1080	0.1387	0.0139
ECG 4	0.1137	0.1097	0.0110
ECG 5	0.1146	0.1065	0.0107

V. CONCLUSION

The experiment lossless compression of ECG signals and transmission results in the low compression ratio if the prediction of the signals is close to the incoming signals. The data compression in biomedical field helps for the reduced storage of the ECG signals and to reduce the transmission bandwidth. It also increases the transmission rate. The related cost for the transmission can also be reduced. The proposed work is to design a suitable compression algorithm with low compression ratio and increase transmission rate with reduced transmission time. This helps to transmit the ECG to the Doctors mobile phone at a faster rate which helps the Doctor to view the ECG waveform and to diagnose the various cardiac diseases even from a distant place.

We can further increase the performance of regenerated ECG signal by increasing the number of epochs and hidden layers. The drawback of the system is that, at the time of network failure or low network availability the android application will not work properly.

REFERENCES

[1] DiscoveryHealth.com writers The Heart: Introducing One Tough Muscle .

[2] American Accreditation HealthCare Commission - MedlinePlus

[3] Anonymous, “A Comparison of single lead ECG data Compression Techniques”.

[4] ECG Signal Compression Using Different Techniques K. Ranjeet, A. Kumar, and R.K. Pandey

[5] R. Kannan and C. Eswaran, “Lossless compression Schemes for ECG Signals Using Neural Network Predictors”, 2007

[6] Simon Haykin“ Neural Networks, A comprehensive foundations, volume2, page2”,2001.

[7] RidhaIskandar and I WayanSimri W “Compression of ECG Signal Using Neural Network Predictor and Huffman Coding”

[8] Al-Hinai, N., Neville, K., Sadik, A.Z., Hussain, Z.M.: Compressed Image Transmission over FFT-OFDM: A Comparative Study. In: Australasian Telecommunication Networks and Applications Conference, pp. 465–469 (2007)

[9] llen, V.A., Belina, J.: ECG data compression using the discrete cosine transform (DCT). IEEE Proceedings, Computers in Cardiology, 687–690 (1992)

[10] Batista, L.V., Melcher, E.U.M., Carvalho, L.C.: Compression of ECG signals by optimized quantization of discrete cosine transform coefficients. Medical Engineering & Physics 23, 127–134 (2001)

[11] Cheshire Engineering Corporation - Basic Concepts for Neural Networks - NeuralystTM User's Guide, Chapter 3.