ECG DATA COMPRESSION BY ARTIFICIAL NEURAL NETWORKS

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Abstract: *Electrocardiogram (ECG) data compression algorithm is needed that will reduce the amount of data to be transmitted, stored and analyzed, but without losing the clinical information content. A broad spectrum of techniques for ECG data compression have been proposed during the last three decades. In this work, utilizing artificial neural networks (ANN) ECG data compression is done by software. In teaching mode, ECG signals are applied both input and output of ANN structure by using the principle of ANN work. So, obtained weight parameters provided a base for next ECG samples.*

INTRODUCTION

The continuing proliferation of computerized electrocardiogram (ECG) processing systems along with the increased feature performance requirements and demand for lower cost medical care have mandated reliable, accurate, and more efficient ECG data compression techniques. The practical importance of ECG data compression has become evident in many aspects of computerized electrocardiography including: a)increased storage capacity of ECG's as databases for subsequent comparison or evaluation, b) feasibility of transmitting real-time ECG's over the public phone network, c) implementation of cost effective real-time rhythm algorithms, d)economical rapid transmission of off-line ECG's over public phone lines to a remote interpretation center, and e) improved functionality of ambulatory ECG monitors and recorders.

The main goal of any compression technique is to achieve maximum data volume reduction while preserving the significant signal morphology features upon reconstruction. Conceptually, data compression is the process of detecting and eliminating redundancies in a given data set. Redundancy in a digital signal exists whenever adjacent signal samples are statistically dependent and/or the quantized signal amplitudes do not occur with equal probability. However, the first step towards ECG data compression is the selection of minimum sampling rate and wordlength. Consequently, further compression of the ECG signal can be achieved by exploiting the known statistical properties of the signal.

Data compression techniques have been utilized in a broad spectrum of communication areas such as speech, image, and telemetry transmission. Data compression methods have been mainly classified into three major categories: a) direct data compression, b) transformation methods, and c) parameter extraction techniques. Data compression by the transformation or the direct data compression methods contain transformed or actual data from the orginal signal. Whereby, the orginal data are reconstructed an inverse process. The direct data compressors base their detection of redundancies on direct analysis of the actual signal samples. In contrast, transformation compression methods mainly utilize spectral and energy distribution analysis for detection redundancies. On the other hand, the parameter extraction method is an irreversible process with which a particular characteristic or parameter of the signal is extracted. The extracted parameters (e.g., measurement of the probability distribution) are subsequently utilized for classification based on a priori knowledge of the signal features.

Existing data compression techiques for ECG signals lie in two of the three categories described: the direct data and transformation methods. The direct data compression techniques are: ECG differential pulse code modulation and entropy coding, AZTEC, Turning-point, CORTES, Fan and SAPA algorithms. Some of the transformation methods are: Fourier, Walsh and Karhunen Loeve transforms. Direct data compression techniques for ECG signals have shown a more efficient performance than the transformation techniques in regard particularly to processing speed and generally to compression ratio /1/.

While it is done any comparison among ECG data compression techniques, the following properties are determined:

1) Signal sampling frequency (f_0):
In analog/digital converter utilized to convert ECG signals to digital the sampling frequency can be different frequencies in accordance with purpose but generally has been selected at 500 Hz.

2) Bit numbers in digital samples (p,"precision"):
Bit numbers which show resolution of stored ECG data can be 8 or 12 bits.

3) Compression ratio (CR):
This is one of the important parameters in data compression algorithms and the large value of this ratio shows success of any algorithm.

$$CR = \frac{\text{The number of samples before compression}}{\text{The number of samples after compression}} \quad (1)$$

4) Performance index (PRD, "Percent Root Mean Square Difference"):

PRD is other one of the important parameters of any algorithms and the small value of PRD shows success of algorithm.

$$PRD = \sqrt{\frac{\sum_{i=1}^{n}\left[X_{org}(i) - X_{rec}(i)\right]^2}{\sum_{i=1}^{n}\left[X_{org}(i)\right]^2}} \cdot 100 \quad (2)$$

where X_{org} and X_{rec} are samples of the orginal and reconstructed data sequences.

5) The higher speed of any algorithm is, the quicker the process can be done and real-time studies can be done.

6) Most of the databases utilized in evaluating ECG compression algorithms are nonstandart. However the algorithm results can be different in accordance with databases /2/ .

ARTIFICIAL NEURAL NETWORKS (ANN)

ANN is an information processing system which information spreads parallel on. This system consist of processing elements connected by single sided signal channels (connections). The number of output signals is one, but it can be increased. ANN can determine its conditions and adjust itself to provide different responses by using inputs and desired outputs which are given to the system.

Recently, it has been shown that neural networks have abilities to solve various complex problems. On the other hand, multilayered feedforward network has a better ability to learn the correspondence between input pattern and teaching values from many sample data by the error backpropagation algorithm. Therefore, in this work, we used three-layered feedforward neural networks and taught them by error backpropagation. Fig.1 shows a general structure of a neural network /3/.

RESULTS

In this work, using artificial neural network (ANN) compression and reconstructed of the some ECG's are done. These ECG's are from MIT/BIH database tapes 100, 107 and 109. Tapes 100, 107 and 109 are respectively normal, paced beat and left bundle branch block ECG's. Orginal data sampled at 360 Hz..

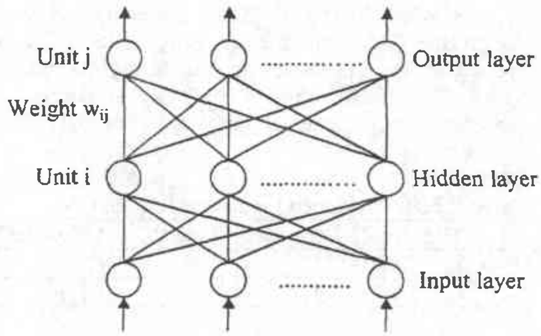

Fig.1. Ordinary type neural network.

Compression processing which is run on computer with Pentium-75 microprocessor in Borland C is provided, as above mentioned, with 200 input nodes, 10 and 5 hidden nodes and 200 output nodes. At the same time, these values give compression ratio, i.e. 20:1 and 40:1. Therefore the utilized ANN structures are as 200:10:200 and 200:5:200. Generally, 20 cycles from ECG's are used in training process. As above mentioned, learning coefficient (ε) and momentum (α) must be selected to minimize the error in training process.

Reconstructed processing for compressed ECG is provided with 10 input nodes (because of 10 hidden nodes in compression) or 5 input nodes (because of 5 hidden nodes in compression) and 200 output nodes. Number of hidden nodes are selected to minimize the error along with ε and α. For normal ECG, orginal and reconstructed ECG is shown in Fig.2. An advantage of this technique is to compress large numbers of data, i.e. 10 cycles (samples) from ECG's are used for training and 100 cycles (samples) can be compressed.

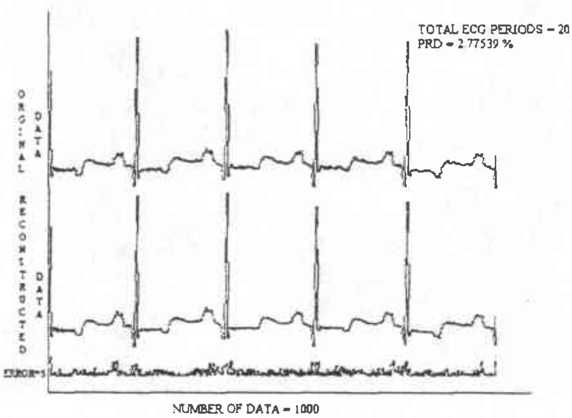

Fig. 2. Graphics of the orginal and reconstructed ECG from MIT/BIH tapes 100 for 10 hidden nodes, and graphics of difference (5 times) between them.

When PRD's of ECG's are compared, it is shown that PRD's in structure using 5 hidden nodes are higher than those in structure using 10 hidden nodes. The small value of PRD shows succes of algorithm. PRD's obtained for 20 cycles of ECG's are shown in Table 1 /4/.

Table 1. PRD's obtained for 20 cycles of ECG's

	Hidden N.	Tape 100	Tape 107	Tape 109
PRD	10	2.77	0.29	0.77
(%)	5	3.91	1.40	1.64

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