International Journal of Engineering & Technology, 7 (4) (2018) 3402-3405

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET
doi: 10.14419/ijet.v7i4.14513
Research paper

Robust multichannel EEG signals compression model based on hybridization technique

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Abstract

Tele monitoring of Electroencephalogram (EEG) via wireless is very critical as EEG. EEG medically is a tool test used to estimate the electrical activity of the brain. There are many channels through which EEG signals are recorded consistently and with high accuracy. So the size of these data is constantly increasing, need large storage area and a bandwidth for the transmission of the EEG signal remotely. In last decade, the EEG signal processing grew up, additionally; storing and transmitting EEG signal data requirement is constantly increasing. This article includes the analysis method of an EEG compression and de-compression. This method is evaluated on the basis of various compression and parameters quality such as CR (compression ratio), SNR (Signal to noise ratio), PRD (percent-root-mean-square-difference), quality score (QS), etc. The steps of EEG compression are pass through many stages: 1. Preprocessing and after that classification. 2. Linear transformation, and [3]. Entropy coding. The EEG compression is specified during processing and coding algorithm for each of the steps. The decompression process is the reverse of the compression process, reconstructs the EEG original signals by using lossy algorithm but with the simple loss of significant information. The proposed compression method is a bright step in the compression field where getting a high compression ratio.

Keywords: *Artificial Neural Networks(ANN); Genetic Algorithm (GA); Multichannel Electroencephalogram (EEG); Principle Components Analysis (PCA),; Fast Fourier Transform (FFT); Tele monitoring.*

1. Introduction

The Electroencephalogram (EEG) used in almost all the brain-related problems for initial diagnosis. Many brains problems turn the electrical signature of the brain in different ways. The basic step in neural disorder recognition is acquisition as long-term EEG signals, analysis it, storage, and processing. Generally, EEG signals monitoring systems are a constantly acquisition, computerized and digital storing of the records. This needs a big storing capacity and large bandwidth transmission in the digital telemedicine systems for remote EEG signals analysis. The objective of this article is developing an efficient method for EEG signal storage and transmission these signals via wireless sensors networks (WSNs) in order to introduce the optimized medical services from physicians to reach to the remote areas. The compression of EEG signals are implemented by using both PCA(Principle Component Analysis), FFT(Fast Fourier Transform) with mixed model consists of artificial neural networks (ANN) and 7 EEG signals surveillance tools, real-time EEG signal compression and efficient memory transfer mode and channel usage bandwidth are required. EEG signals compression techniques should be developed for a mobile device taking into account many aspects such as account complexity, the amount of information loss, quantization and other noise effects . EEG data compression techniques can be categorized into three ways. Firstly, the direct data compression technique that analyzes and compress data directly in the time domain. Secondly, the transform technique, that converts the signal in time domain to frequency domain or other fields and analyzes the energy distribution. Thirdly, include parameter extraction compression techniques that extract signals features and parameters. Many researchers have proposed many methods of compressing EEG signals based-on the three algorithms listed above. The propose compression method uses a combination of PCA, FFT, ANN and GA techniques for reliable outcomes.

2. Related work

Many related works are introduced in the field of EEG compression, and below mention of some of the related work:
In 2012, N. S. present presents a novel and efficient high-performance lossless EEG compression using WT and ANN predictors [1]. In 2013, Z. Z. et al. present a proposed study to use the structure of block sparse Bayesian learning, which has superior efficiency to another existing Compressed Sensing algorithms in retrieve non-sparse signals to overcome the problem of EEG is not sparse signals in the time-domain not sparse in transformed-domains[2]. In 2013, D.D. et al., present an efficient method for single or multichannel EEG compression using EZW method as this method gives gradually encoding which can be stopped anywhere or depending upon required bit rate [3]. In 2013, S.U et al. present a new and easy preprocessing method of arranging EEG in matrix form before compression [4]. In 2014, R.M., present a high-performance hybrid multichannel EEG compression algorithm based-on frequency transformation and parameter extraction methods [5]. In 2015, S. C. et al. improve an effective algorithm EEG lossless compression by using the WT followed by AC (arithmetic coding) on the residual [6]. In 2016, K. et al. developed a lossless

hybrid EEG compression method based on the characteristic of DCT frequency spectrum and the Huffman coding [7].

3. EEG compression method

a) Compression method flow Process

Many researchers have suggested different ways to compress/reconstruct EEG data. Fig. (1) Shows the compression procedure of the EEG compression technique.

1) EEG Signal Preprocessing and Classification: This phase is used for preprocessing of the main EEG signal. It can include a preprocessing filter, feature extraction of EEG, classify EEG signals, detect peak and down sampling. The filter is selected according to the frequency response of EEG signals. The aim of this filter to EEG signals de-noising. If the frequency of sampling of the main EEG signal is > 200 or =200, and this EEG signal can be taken by a sample of [2] to form a signal greater than or equal to 100Hz. The signals are processed on each round of EEG signal. Thus, each peak must be detected to separate each round from EEG signal. There are many current literatures are obtainable on peak detection for periodic reference. However, this article suggests an easy model of EEG signal to detect a peak based-on EEG signaling features [8].
2) EEG Linear Transformation: The second phase of the EEG compression scheme is the linear transformation of the input EEG signal. For example FFT or PCA, etc. In EEG signals reconstruction procedure, an inverse linear transform is utilized. In this article, a Fast Fourier Transform (FFT) and Principle Component Transform are selected [9].
3) Entropy Coding: Previous phase output include several samples with a various probability. Entropy coding is a kind of lossless compression of digital computerized data by performing patterns often appeared with a little bits and patterns sometimes occurred with more bits. There are mainly two common entropy coding methods, Hoffman coding and arithmetic coding. The Huffman-coding scheme is used in this compression algorithm. In Huffman-coding, each code that assigns the varying length code, reliant on its probability [10].

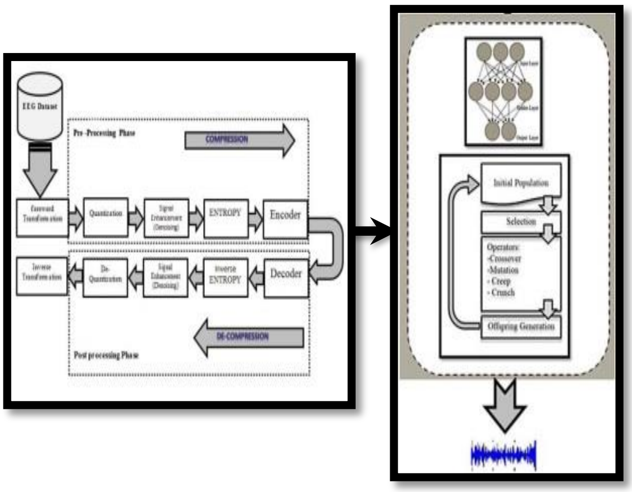

Fig. 1: Proposed Compression Process of Hybrid Proposed Algorithm.

4. The EEG compression scenario

a) Compression Phase

Various samples are from the Gleneagles Private Hospital(GlPH) database in Malaysia, for (200) patients samples with Epilepsy, Alzheimer's disease, and different brain injury. Fig.(2), show simple sample of normal EEG signals[11]

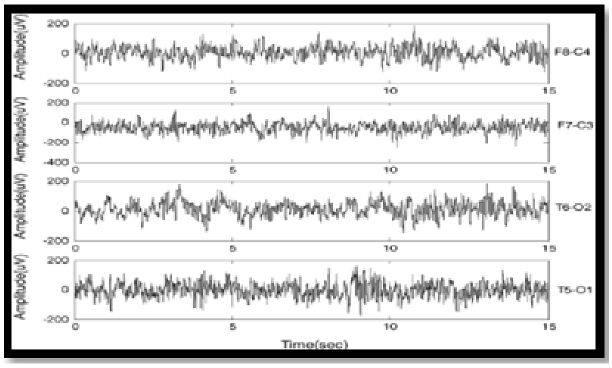

Fig. 2: Sample of Normal EEG Signal.

1) EEG Signal Pre-processing

The exemplary EEG signal contains a power line noise. Therefore, there is a necessity to extract the accurate EEG feature to eliminate such noise. To creat the appropriate prefilter for signal denoising, each EEG signal is decomposed with the frequency response. The chosed signals had a sampling frequency of 360 samples/sec. Thus, using the Nikyst standards the frequency response range was chosen as 0Hz - 180Hz. The signals are shown in the frequency range from 0 Hz -50 Hz in the lower range and 130 Hz - 180 Hz on a higher scale. Thus, a bandstop filter of comparable ranges can be used for EEG signals preprocessing. When the original signals have resolution high, then these signals can be down-sample. The sampling frequency of these real (original) signals are 360, then the original signal is down-sampled by a factor of 2 [12].

2) Peak detection:

Top signal peaks are detected at peak detection method. The proposed peak detection technique depend on the features of the EEG signal. One of the features of EEG is peak threshold amplitude. threshold amplitude is the minimum possibility value of the peak. The values below this threshold are not peaked. The second EEG attribute is the minimum distance between the tops of the bottom). The peak detection method suggested here is described. Firstly, specify the maximum value within certain samples. If the maximum value is larger than the threshold, then the peak is considered. Samples adjacent to the earlier discovered peak may be larger than the peak threshold amplitude. Thus, to detect the coming peak, all neighbor samples are cleared from current detected peaks. This will bypass detection of the pseudo-peak of samples adjacent to the peak that was recently detected [13].

3) Linear transformation:

The EEG signal is rated in multiple round. Each round consists of a sample between two sequential peaks. Each EEG round, a separate FFT is computed. FFT values are measured for storage objective. Different quantification factors ranging from 0: 1 to 4 are chosen to analyze the quantization impact.

4) Entropy Encoding (Hoffman coding):

The Huffman coding is chosen for the entropy encoding. Because repeated signal of EEG, FFT can be predicted. Some of the FFT values occurs with high probability. After calculating an FFT, a histogram is considered for each FFT value. The frequency graph shows the occurrence of each of the FFT value. Thus, the probability of each FFT sample value can be computed. Most of the values of the FFT sample were found to have a range of -20 to +20. Other values are unpredictable at all [14].

5) Encoding values FFT Sample:

Each FFT value calculated on the coding is fed. The encoder test if the input value is section of the FFT values specified in the Huffman Dictionary. If the input value is part of the Huffman Dictionary, the input value is then fed into the Huffman encryption. Encryption adds encrypted code Huffman to a little stream using the Huffman Dictionary.

b) EEG signals Reconstruction phase:

EEG signals reconstruction phase or decompression procedure is the reverse compression procedure. This decoding phase includes the entropy signal coded, inverse linear transformation and post-processing. The EEG constructed signal is created to regenerate. The EEG signal is given as input to the decompression process [15].

1) Decoding of Entropy Coded Signal:

There are two types of bits encoded in a compressed signal. Firstly, a stream that contains Huffman encoding codes is fed to the Huffman decoder. Huffman decoder decodes the bits using the Huffman Dictionary. Then, the second bit-stream decoder, which is without Huffman coding codes. The values in the second-bit train contain the values of FFT and its indexes in the original vector. The values in these indexes are assigned to the Huffman block previously decoded with the values of the FFT above-mentioned in the second-bit stream [16].

2) Inverse linear transformation:

FFT was used for linear transformation at the compression stage. Thus, inverse Fourier transform (IFF) is used in reverse process. An IFFT is computed for each cycle. Each round depend on of a sample between two consecutive peaks. The output of the reverse entropy encoding is divided into multiple cycles based on peak indicators. Then, it is fed to the EFT block. The EEG signal output will be rebuilt with some tolerance due to the quantization used in the compression phase. In the next fig. (3), show the EEG before compression and after reconstruction [17].

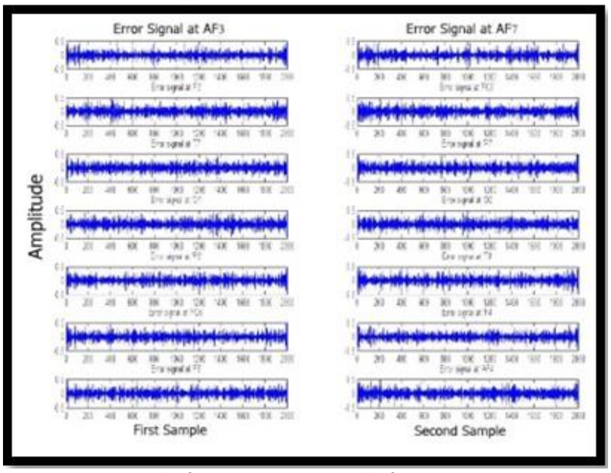

Fig. 3: EEG before Compression and after Reconstruction.

3) EEG Signals post processing: in post processing, the IFFT signal is fed up for samples. Then, the output of the samples is fed up to the band-stop post processing filter. A generated signal is rebuilding EEG signal. This compares with the original reference to estimate the performance of the suggested technique [18].

4) ANN and GA: A New Hybrid Training Model

The proposed model consists of artificial intelligent mixed systems, network (RBF) MLP (GA). One of the newest for use with ANN include the hybridization of two types of network methods. The scientific truth behind the hybrid network is a succession of steps of identical or non-identical network models of the examples to function as building blocks in the analysis of a complex data structure. The proposed hybrid program was sophisticate using RBF networks to minimize the scope of the problem analysis network (MLP). Note that the network function (RBF) collects the characteristic features of distinctive features. The network (MLP) disposed of such categories of desired characteristics as recognized entities. To improve network performance, by comparing the work of each network individually. These artificial intelligent network size calculated by the number of weights required for each network (RBF) and (MLP), then advance the result of the genetic algorithm directly. These outcomes display that the hybrid technique can have useful results. Additionally, each level of the network can be adjusted with a various model to achieve the best results. Other advantages of using the hybrid network are to improve the speed of convergence and the reliability of networks and correct the cases of error in the global minimum by developing the structure of the input form and network RBF (MLP). The disadvantage with hybrid networks suffers the loss of data accuracy. To remedy this problem, reduce the amount of input data in the first step and move that input with robust functionality. This leads to improved system speed, accuracy, and efficiency. Comparison (RBF) with other types of artificial neural networks note that the network (RBF) achieves very high accuracy for most data sets. Initially, the input signals of robust characteristics introduced into the two networks (RBF) and (MLP) to start learning. Once the neural network complete training and learning, the input signals were checked by EEG (GA) unchecked by the two artificial neural networks to obtain an optimal solution [19].

5) Performance of the Selected Parameters

a) CR(Compression Ratio)

CR can be defined as a ratio between no. of bits and compressed signal.

CR (%) = Number of Encoded Samples/Total number of Signal Sample*100 (1)

b) PRD(Percent RMS Difference)

The format of percentage root mean-square difference (PRD) in most EEG compression algorithms can be defined as a following:

PRD (%) = Reconstructed Noise Energy 1/2 Original Signal Energy/*10 (2)

c) PRDN(Percent RMS Difference Normalised)

Normalized Percent Root-mean-square Difference can be defined as the following format:

PRDN (%) $=\sum_{n=1}^{N}\big(x(n)-y(n)\big)2/\sum_{n=1}^{N}(x\ (n)-y)2$ *100 (3)

Where x represents the original EEG signal and y is represent the reconstructed EEG signal.

d) Quality Score (QS)

It is the ratio between CR and PRDN as a follow:

QS= CR / PRDN (4)

e) Signal to-noise- Ratio(SNR)

The format of SNR as a following:

PRDN (%) = 10× log $\sum_{0}^{N-1}(x(n)-mean\ (x))2$ / $\sum_{0}^{N-1}(x(n)-y(n))2$ (5)

Where x represents the original EEG signal and y is represent the reconstructed EEG signal

6) Experimental Outcomes and Discussion

In this manuscript, proposed robust hybrid model consists of FFT, PCA, and ANN, GA based EEG signals compression. The proposed manuscript records from Gleneagles Private Hospital (GlPH) database in Malaysia and the model test under 200 records for different patients. Table 1. The performance of proposed algorithm with a sample of 15 different EEG signal records by using PCA and FFT algorithms.

The performance analysis per channel of proposed hybrid multichannel EEG compression scheme in terms of main parameters, (a) CR, and (b) PRD, using both FFT and PCA.

Table 1: The Performance of Proposed Algorithm with a Sample of 12 Different EEG

FFT + PCA					
EEG SIGNALS RECORDS	CR	PRD	PRDN	QS	SNR
100	14.8	2.26	0.65	6.45	49.9
101	12.6	2.24	0.34	6.76	50.7
102	16.2	0.63	0.11	14	88.3
103	7.80	1.3	0.82	8.93	62.8

104	9.80	2.03	1.61	4.84	64.4
105	10.2	1.43	1.33	8.99	61.8
106	9.00	1.5	0.30	7.6	63.4
107	11.2	1.03	0.71	5.95	81.3
108	6.15	1.17	0.23	9.28	68.6
109	11.6	1.2	1.69	7.84	72.7
111	15.0	1.96	0.44	5.99	62.1
112	11.5	4.15	3. 89	3.47	51.4
Average Values	11.41	1.74	1.12	7.5	64.78

Table 2: The Performance of Proposed Algorithm with a Sample of 12 Different EEG Signal Records by Using Hybrid Proposed Algorithms

Hybrid Algorithm (FFT + PCA) and (ANN +GA)					
EEG signals Records	CR	PRD	PRDN	QS	SNR
100	14.93	2.3	0.69	6.79	50.0
101	11.99	2.5	0.41	6.81	50.9
102	15.98	1	0.21	13	88.89
103	8.91	1.4	0.88	9.1	63.1
104	10.98	2.1	1.90	4.90	6477
105	14.97	1.51	1.52	9.0	61.92
106	10.3	1.7	0.4	7.9	63.19
107	10.9	1.9	0.90	6.01	81.24
108	6.77	1.2	0.5	9.50	68.91
109	13.91	1.23	1.92	7.91	72.62
111	14.55	1.2	0.76	6.09	62.75
112	12.9	4.3	3. 99	3.32	51.18
Average Values	12.257	1.86	1.71	7.9	65.31

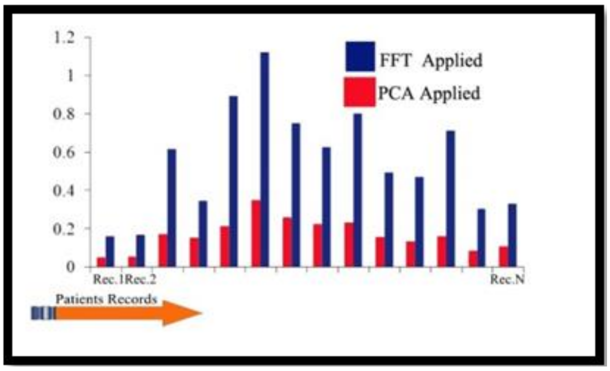

Fig. 4: Bar Chart of EEG Multichannel with Applied FFT and PCA Algorithm for Different Patients Records.

5. Conclusion

The manuscript describes different steps of EEG compression and it tries to developed and expand these steps as compare to both FFT, PCA algorithm and the hybrid proposed algorithm. The analysis of frequency response of EEG signal described in the manuscript used to designing convenient preprosing filter. The characteristics of EEG signal based simple EEG peak detection. The algorithm of Huffman encoding used for a subset of all possible FFT values to attain a preferable EEG signal compression. The explained technique realize compression of EEG signal with low-computational complexity. It uses standard digital processing algorithms. This hybrid proposed technique can be simply perform in the various embedded systems.

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