Department of Electrical and Computer Engineering

Low Frequency Sub-Band Prediction for Real-Time EEG Compression

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Introduction

Recording of Electroencephalogram (EEG) is done over several hours and along several channels. The recording can result in huge amounts of data to be stored and/or transmitted, which calls for efficient and near lossless compression techniques. A novel technique for real-time Electroencephalogram (EEG) compression that makes use of the redundancy between the different frequency sub-bands present in EEG segments of one channel is proposed. It uses Discrete Wavelet Transform (DWT) and dynamic reference tables to compute and send the decorrelated sub-band coefficients. Set partitioning in hierarchical trees (SPIHT) is also used as source coder.

Correlation between EEG sub-bands

Brain activity of EEG signals is usually divided into four main frequency rhythms: delta (0 - 4 Hz), theta (4 - 7 Hz), alpha (8 - 12 Hz), beta (12 - 30 Hz) and gamma (30 - 100 Hz). An EEG segment is characterized by the presence or absence of certain rhythms. They help identify the functional states of the brain. Dividing the EEG into different sub-bands can be used to highlight the similarities between the segments. The energy distribution of the EEG signal in time and frequency in each sub-band is reflected in the DWT coefficients.

Method

Reference lists, $\mathcal{R}_s$, that contain the level s DWTcoefficients of certain selected segments are used to decorrelate the DWT coefficients of the two lowest frequency sub-bands. The correlation coefficient between the DWT sub-band coefficients of level s of a certain segment and all references in $\mathcal{R}_s$ are calculated and the maximum value at index I_s is then compared with a certain threshold, T_r. If this maximum value is larger than T_r, then the following residual is found for DWT sub-band s and segment index i:

$$\boldsymbol{d}_{l,s}[i] = \boldsymbol{d}_{l,s}[i] - w_s \boldsymbol{\mathcal{R}}_{l,s}[I_s]$$

w_s is calculated using pseudo-inverse that guarantees to find the minimum (Euclidean) norm solution to the prediction system which is desirable since these weights should be quantized and sent to the receiver. Quantized values of the residual $\boldsymbol{d}_{l,s}[i]$ and the reference index I_s are also sent to the receiver. The coefficients of the remaining sub-bands are coded using a modified version of SPIHT that disregards sub-band level s [1]. Adaptive arithmetic coding is used to entropy code the residuals.

Dynamic Update

The EEG recordings are done over several hours, sometimes even days. The patient can go from an awake alert state, to a relaxed or seizure-like state. The references should be able to adapt to the changes in the characteristics of these recordings. For a particular reference at index f in the list, this dynamic update depends on two factors: count of number of uses, $c[f]$, and the age of the reference, $a[f]$. References that have rarely been chosen and are quite old compared to other references, i.e. were added to the list a long time ago, should be updated. Several equations were tested and the following equation was chosen:

$$r_w[f] = a[f] - 2\,c[f]$$

Simulation and Discussion

Figures 1 and 2 show decoded Sleep EEG segments using bit rates of 4 and 2 bits per sample (bps). A segment size of 128 samples was used and 5-level DWT was performed on each segment. The maximum number of references used was equal to 7.

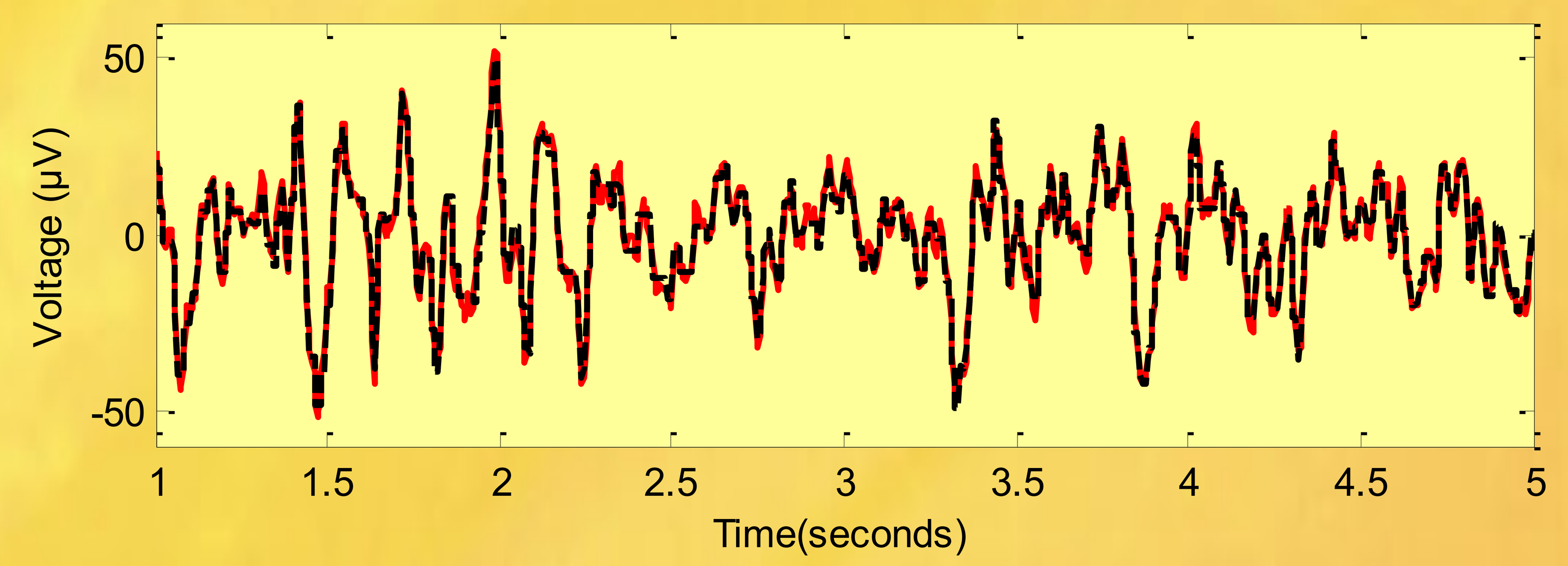

Figure 1: Original (red) and decoded (black) EEG Signal for 2 bps data rate.

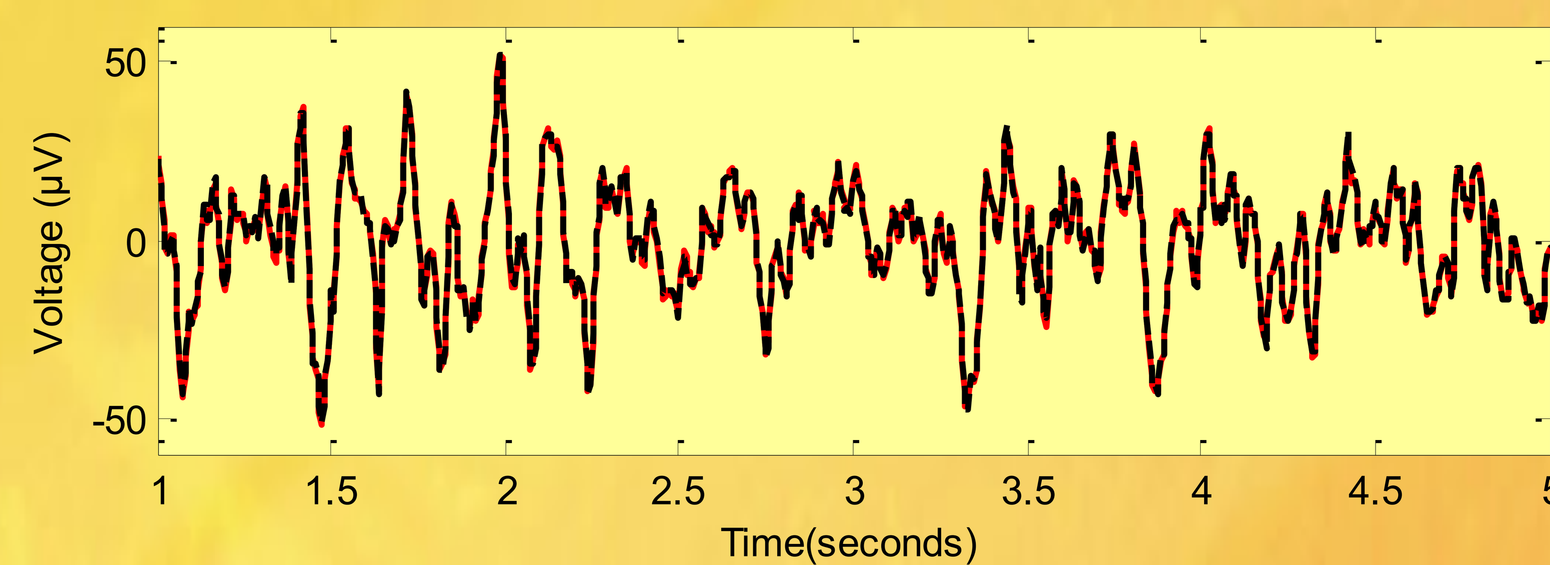

Figure 2: Original (red) and decoded (black) EEG Signal for 4 bps data rate.

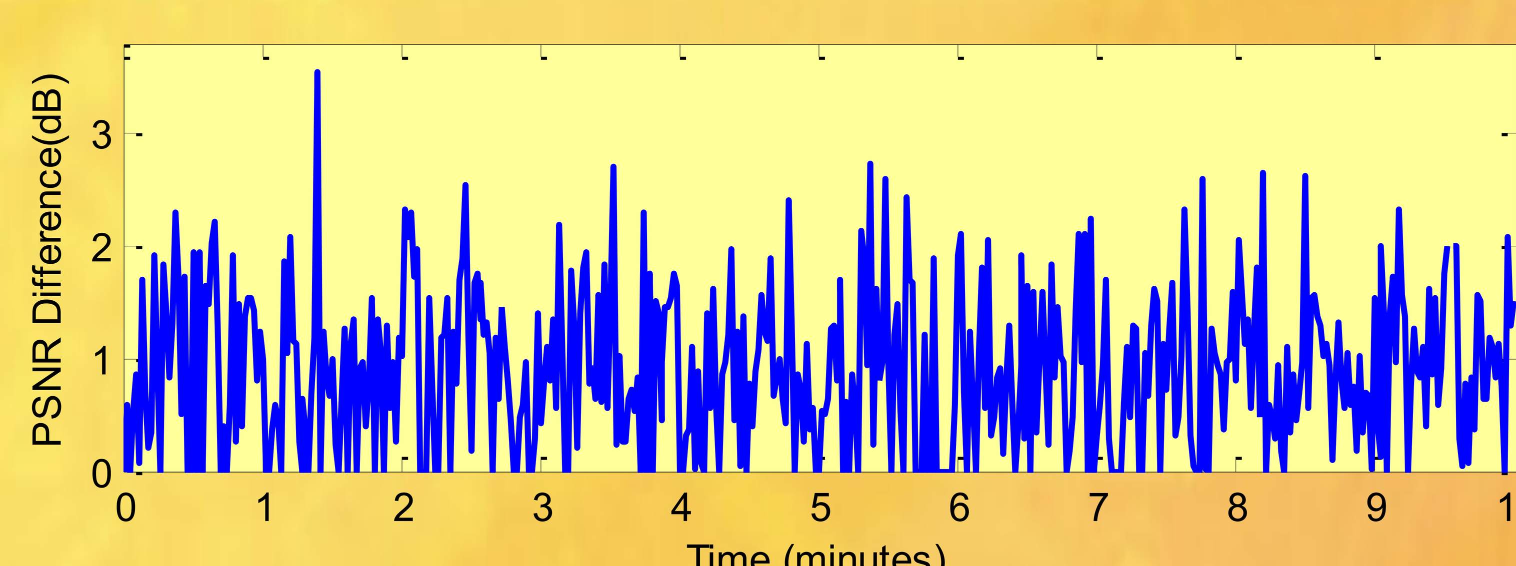

Figure 3: PSNR difference between SPIHT and the new method.

Due to the dynamic update of the reference lists, the compression algorithm is able to adapt to the changes in the EEG recordings. We notice there is no degradation in the performance after a certain time and the references keep changing with time.

Conclusion

Redundancy between different EEG segments in one channel was explored and a technique to make use of this redundancy was suggested. EEG segments can be grouped into several groups based on certain features for manual classification and abnormality diagnosis [2]. Grouping of similar segments is an important tool in compression and is applied indirectly in the proposed scheme.

References

[1] A. Said and W.A. Pearlman, "A new fast and efficient image codec based on set partitioning in hierarchical trees," *IEEE Trans. on Circuits and Systems for Video Technology*, vol. 6, pp. 243-250, June 1996.

[2] R. Agarwal and J. Gotman, "Long-term EEG compression for intensive-care settings," IEEE Engineering In Medicine and Biology, vol. 20, no. 5, pp. 23–29, 2001.