A 2-D ECG compression technique based on Dual Tree Complex wavelet Transform and Modified SPIHT

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Abstract
In the paper, a 2-D ECG data compression algorithm based on dual tree complex wavelet transform and modified SPIHT (set partitioning in hierarchical trees) is proposed. The 2-D ECG will be used because of it utilizes correlation between adjacent heartbeats. Dual tree complex wavelet is achieve accuracy in coding. Modified SPIHT used for utilizing the redundancy among medium and high frequency sub band of the wavelet coefficient. ECG signal is converted in 2-D by cut and align, mean removal and normalization. Then apply complex wavelet and modified SPIHT for encoding coefficient. Experimentation on MIT-BIH arrhythmia database is used. Reconstruction is shown with 1-D data.

Keywords—Electrocardiogram (ECG) compression, set partitioning in hierarchical trees (SPIHT), dual tree complex wavelet transform (DT-CWT).

INTRODUCTION

In recent year, computerized ECG processing system developed with increased feature performance requirements and wants lower cost medical treatment with accurate output and it also reliable and more efficient for ECG signal compression, which utilize intra beat and inter beat correlations and it achieve superior performance[1]-[5]. ECG signal is also called electrocardiograph. It is graphical representation of electrical waveform. ECG is records activity of heartbeat over time. For good quality diagnostic of ECG signal, require ambulatory monitoring system for continuous 12 or 24-hour. Because of that, generate huge amount of data of ECG signal each year. Hence, require high storage and it is complicated. In that case, if we compress the data, so data storage require less memory and it is easy to transfer data through telephone line or digital telecommunication network. The goal of compression technique is to achieve maximum feature and reduce volume, when reconstructing the signal. In data compression, remove redundancy in data and it is easy to transfer. For example, when we send any message should be same. It means, message that has unnecessary and has repetitive same meaning, if it remove then sentence will be same or completed. In ECG signal include different frequency component at different time and location. Means it is non-stationary signal. In all transform method, wavelet transform is working in both frequency and time domain simultaneously. For compression of ECG signal, wavelet transform is good method. ECG signal is non-stationary signal, which includes different frequency components at different times and locations. Among the transform methods, wavelet transform may localize the signal analysis in the both time and frequency domains simultaneously. So, it is a good method for the study of ECG signal data compression. In recent years, many wavelet transform based ECG data compression techniques with low reconstruction error and fine visual quality have been proposed. Most of these wavelet-based ECG Compression algorithms disregard the redundancy between adjacent heartbeats and apply wavelet transform directly to the acquired one dimensional (1-D) ECG data. In recent year, their technique is proposed for removal of redundancy in signal and gets good quality of signal with its important characteristic. In ECG signal, there is some similarity between adjacent heart beat. Each beat has almost same frequency and time signal. Some ECG compression technique not utilizes such similarity between each beat of heart. Hence, we use 2D (two dimensional) transform system. It utilizes correlation between adjacent heartbeats. It improves the compression quality of ECG signal. Sheni Chuan Tai, Chia-Chun Sun and Wen-Chien Yan proposed a 2-D ECG compression based on Wavelet and Modified SPIHT using cut and align, preprocessing approach[6].

2-D compression has following steps:
1) QRS detection
2) Preprocessing (it cut the beat and align, period normalization, amplitude normalization, mean removal)
3) Transformation
4) Coefficient encoding
II. DUAL TREE COMPLEX WAVELET TRANSFORM

Recently, discrete wavelet transform (DWT) is applied for various fields in multimedia signal processing, such as compression, denoising and so on. The complex wavelet transform (CWT) is a complex-valued extension to the standard discrete wavelet transform (DWT). It is a 2-D wavelet transform which provides multi resolution, sparse representation, and useful characterization of the structure of an image. The dual tree complex wavelet, proposed by Kingsbury in 1999 has the following properties [7]:

1) Approximate shift invariance
2) Good directional selectivity in 2-dimensional (2-D) and phase information.
3) Perfect reconstruction (PR) using short linear phase filter.
4) Limited redundancy, independent of the number of scales 2:1 for 1-D (2m times for m-D)
5) Efficient order N computation-only twice the simple DWT for 1-D (2m times for m-D)

The filterbank structure for both DT-CWTs is identical. Figure 1 shows 1-D analysis filterbank spanned over three levels respectively. The form of conjugate filters used in 1-D DTCWT is given in equation (1): \( \{h(x)+jg(x)\} \) (1)

The filter \( g_0(n) \) and \( h_0(n) \) are the real-valued low pass and high pass filters respectively for real tree. The same is true for \( g_i(n) \) and \( g_i(n) \) for imaginary tree [8].

As shown in figure 1, \( g_0(n) \) and \( h_0(n) \) are filters of real part; \( g_i(n) \) and \( h_i(n) \) are filters of imaginary part, satisfying the equation (2,3):

\[
\begin{align*}
    h_0(n) &= (-1)^n g_0(N - n) \\
    h_i(n) &= (-1)^n g_i(N - n)
\end{align*}
\]

There are two types of dual tree wavelet transform, the real one and the complex one [9]. It also has six directional sub bands to reveal the details of an image in ±15º, ±45º and ±75º directions with 4:1 redundancy. However, different from the real 2-D dual tree wavelet transform, it has 12 wavelet since in each direction there are 2 wavelets. A) The Q-shift Dual-Tree Filters Unfortunately there are certain problems with the odd/even filter approach:

1) The sub-sampling structure is not very symmetrical.
2) The two trees have slightly frequency responses.
3) The filter sets must be biorthogonal, rather than orthogonal, because they are linear phase.

To overcome all problems above, Kingsbury proposed a Q-shift dual tree[7] and [10], as in figure 2, in which all the filters beyond level 1 are even length, but they are no longer strictly linear phase. Instead they are designed to have a group delay of approximately \( \frac{1}{2} \) sample (q). the required delay difference of \( \frac{1}{2} \) sample (2q) is then achieved by using the time reverse of the tree a filters in tree b. Furthermore, all filters beyond level 1 are derived from the same orthonormal prototype set. This lead to a more symmetric sub-sampling structure, but it preserves the key advantages of DT-CWT that are approximate shift invariance and good directional selectivity. The symmetry of the sub-sampling process is important for hierarchical algorithms which relate wavelet coefficient at one level to those at the same spatial location at levels above or below. Therefore we decompose the input images with Q shift CWT. Here near-symmetric (13, 19) tap filters as the level 1 filters and Q-shift (14, 14) tap filters as the levels 1 beyond are used.

Figure 1. Analysis filter bank for 1-D DTCWT

Figure 2 giving real and imaginary parts of complex coefficients from tree a and tree b respectively. The delay for each filter by considering \( q= \frac{1}{4} \) sample
period. Note that for the Q-shift CWT each complex wavelet basis is centered on the equivalent complex sending function basis, and that each of these is centered between a pair of adjacent complex bases from the previous (finer) level. In this way, each complex wavelet coefficient at level k has two complex children located symmetrically above it at level k -1. For the odd/even DT CWT such symmetries do not occur.

III. SPIHT ALGORITHM

SPIHT algorithm, introduced by Said and Pearlman, is a highly advanced version of the EZW algorithm [11]. By using this algorithm, the highest PSNR values for given compression ratios for a variety of images can be obtained. It provides a better comparison standard for all subsequent algorithms. SPIHT stands for Set Partitioning in Hierarchical Trees. Hierarchical trees refer to the quadtrees as defined in EZW. The term Set Partitioning refers the way these quadtrees divide or partition and the wavelet transforms at a given threshold.

The SPIHT algorithm operates on a wavelet transform image with equal length and width of an integer power of 2. It encodes the wavelet coefficient in a way that uses a hierarchical organization of the coefficients. This encoding sends high order bits of coefficients before low order bits. The SPIHT algorithm only requires anywhere from 1 to log2N steps of the wavelet transform. Energy is concentrated in the coarser approximation (i.e., those coefficients tend to have a larger magnitude) and there is a spatial self-similarity between the parent and child pixels that suggests that an encoding scheme that moves from the parents to the child will exhibit decreasing coefficient magnitude current magnitude threshold. It is a very fast coding/decoding (nearly symmetric) algorithm [11]-[13].

IV. MODIFIED SPIHT

The coding of SPIHT technique is very simple. It produce embedded bit stream and also provide good bit distortion rate performance. But in experimental result, there is disadvantage. In SPIHT algorithm, coefficient of wavelet transformed are arranged in tree form. Significant in that coefficient are sorting by the list LIP, LIS, LSP. In that, there is small part of bit are require to encode the coefficient, which lead to the quality of reconstructed signal is low. For solving this problem, used Modified SPIHT algorithm for encoding (extended zerotree structure). The procedure of extended zerotree structure proposed in [14] as follows:

1) In traditional zerotree structure, highest layer wavelet coefficients are stored in LIP. In extended zero tree store the wavelet coefficient in LIP without their offspring.

2) In standard SPIHT algorithm, coefficient in highest layer store in LIP without calculating whether they are significant or insignificant. But, their offspring need to check. In extended zero tree, the offspring of coefficient are need not to check if it is insignificant in LIS. In extended zerotree, cut down binary digits and enable more significant coefficient to be encoded firstly. Extended zerotree structure may improve the algorithm by shorten the length of LIP and hence extra memory are not needed. Also, it shortens the length of LIS, which capture the information of insignificant bit effectively and increase the proportion of significant coefficient in LIS. Advantages of MSPIHT algorithm:
   1) Shorten the LIP and LIS it make less cost and want less time for encoding.
   2) For more significant coefficient are given priorities for encoding.

V. ALGORITHM USED TO COMPRESS ECG SIGNAL

In transform based image coding methods wavelet is the well known tool. The figure 3 shows the system implementation based on DWT/DT-CWT and MSPIHT algorithm.

![Figure 3. Block diagram of the proposed ECG compression method. (a) Encoder and (b) Decoder.](image)

The ECG signal are used as input to the system, the ECG signals \(x = [X_1 \ X_2 \ X_3 \ X_4 \ \ldots \ X_N]\) is preprocessed by normalization and mean removal using the following relation: \(Y(n) = x(n)/A_m - m_x\), \(n=1,2,\ldots,N\) (3) Where, \(x(n)\) and \(y(n)\) are the original and normalized signal samples respectively and \(N\) denotes the length of the original signal. \(A_m\) and \(m_x\) are the maximum value of the original ECG signal and the average of the normalized ECG signal respectively. The ECG signal is normalized by dividing the original signal by its maximum value.
Am. Mean removal is done by subtracting from the normalized ECG signal its mean $m$ to reduce the number of the significant wavelet coefficients. After that, the ECG signal is cut into $M \times N$ blocks and align the blocks. In one heartbeat the P wave, QRS complex and T wave is available. Same type of waveform is present in each heartbeat of ECG signal hence cut each heartbeat waveform for convert it in 2-dimension. Each block contains nearly same waveform. For Correlation of each heartbeat cut the signal after T wave. Then align all the blocks for image. When image is produced then apply DT-CWT on image. Two methods are used to find the wavelet transform such as three level decomposition of input image using DWT with bior4.4 wavelet. Bior4.4 wavelet is selected based on trial and analysis of the system, or three level decomposition of image using Q-shift DT-CWT with near-symmetric 13/19 tap filter for level 1 and Q-shift 14/14 tap filter for level 2 onwards are used to decompose the image and to generate the wavelet coefficients followed by an encoding process. The Modified SPIHT encoding algorithm is used to encode the wavelet coefficients. The output of the encoder is a compressed signal. Now reverse processing is carried out for decomposition part to obtain the reconstructed image from the compressed image. The SPIHT decoder is used to decode the wavelet coefficient and then inverse DWT or inverse DT-CWT are performed to get the reconstructed image. Then, restore the image in 1-D ECG signal.

CONCLUSION

To conclude the project, it is an approach for ECG signal compression using dual tree complex wavelet transform with modified SPIHT progressive coding technique is used to improve the quality of reconstructed ECG signal with high compression ratio. Also, 2-D DT-CWT based ECG compression approach utilize the long term and short term correlation between adjacent heartbeat. The performance of QRS detector is affected by various noises. So, accurate QRS detector is invariant to different noise. The DWT has some disadvantages like absence of phase information, lack of shift invariance and lack of directional selectivity, which are solved by using DT-CWT. DT-CWT algorithm used for representing magnitude and phase offset encodes the shift. The Modified SPIHT has proposed which utilize a high signal to noise ratio and great subjective visual character. Encoding speed of MSIPIHT is fast and it also has the characteristics of embedded code. All these characteristics make suitable for compression of ECG signal. Using MIT-BIH arrhythmia database simulation experiment have been conducted and also, several algorithm based on wavelet transform are tested and compared with modified SPIHT algorithm. The proposed algorithm shows that 2-D Dual Tree-Complex Wavelet Transform and Modified SPIHT based ECG compression algorithm can achieve the better compression performance than other compression performance.

REFERENCES


