A Hybrid Approach of Image Coding using Neural Network and Wavelet Transform

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*Abstract--***Digital images requires more storage space and high data rates for transmission which influences us to innovate efficient image compression systems. In this paper we are implementing a hybrid image compression system by using discrete wavelet transform, neural networks and Differential Pulse Code Modulation based on the predicted sample values. Scalar quantization and Huffman encoding schemes are also used for compressing different sub-bands. In this method we can achieve satisfactory reconstructed images with increased bit rates and large Peak Signal to Noise Ratio (PSNR).**

Keywords-- DWT(Discrete Wavelet Transform), Neural network, DPCM(Differential Pulse Code Modulation).

I. INTRODUCTION

Aim of image compression is to reduce redundant data bits. It plays an important role in development of multi-media, computer and telecommunication applications as in case of interactive education, video conferencing etc.[4] Memory and bandwidth are the important constraints in image storage and transmission. The image compression technology consists of three important steps: pixel transforms,quantization and entropy coding. The pixel transforms is to convert the input image into another space where image can be represented by uncorrelated coefficients or frequency bands.Quantization, in mathematics and digital signal processing, is the processof mapping a large set of input values to a smaller set like rounding values to some unit of precision. Aalgorithmic function that performs quantizationis called a quantizer. The error introduced byquantization is referred to as quantization error or round-offerror. Entropy coding is a lossless data compression in which information of input data is considered to reduce the redundancy. Various types of lossless compression algorithmsare arithmetic coding, Huffman coding[4] and run-lengthcoding etc. The main is tocompress images by reducing number of bits per pixelrequired to represent it for storing or transmission ofimages and then reconstructing back by decoding theHuffman codes.

II. IMAGE COMPRESSION TECHNIQUES

Image compression techniques are mainly classified into 1.lossy image compression and 2.lossless image compression.Lossy image compression results in lost data and quality from the original version. Lossy compression is associated with image files like, such as JPEG's, can also be used for used for audio files, like MP3's or AAC files. Lossless image compression is an algorithm that allows the original data to be perfectly reconstructed from the compressed data. Lossless data compression is used in many application. For example, it is used in ZIP format and in the GNU tool gzip.

A. DiscreteWavelet Transform

Wavelet analysis represents the next logical step: a windowing technique with variable-sized regions. Wavelet analysis allows the use of long time intervals where we want more precise low-frequency information, and shorter regions where we want high-frequency information. Wavelet transform on a signal is as shown in the figure 2.1.1 below.

Figure 2.1.1: Wavelet transform on a signal[2]

The wavelet transform on a signal is compared with the other types of transformation techniques like time based (eg. DFT), frequency based (eg. FFT), and STFT (eg.DCT).
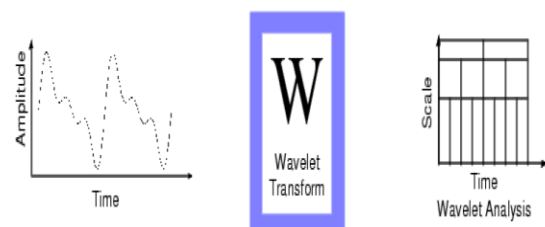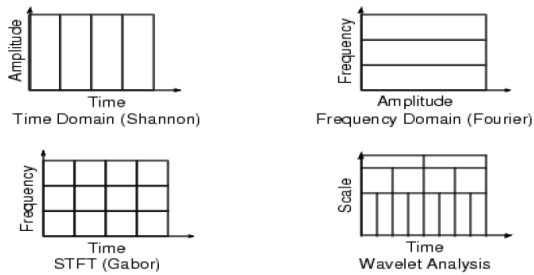
Figure 2.1.2: Comparison of various types of transform techniques[2].

In DWT, an image is represented by sum of wavelet functions, having different location and scale. Wavelet is a mathematical function by which one function can be transformed into another. It performs multi-resolution image analysis, which means simultaneous on different resolution levels. In 2D wavelet, following pair of waveforms will be needed to decompose an image of MXN matrix:

1) One to represent the high frequency to the detailed part of the image (wavelet function)

2) Another for low frequency or smooth parts of an image (scaling function). Fig.2.1.3 shows wavelet filter decomposition. For level n, the sub-bands are labelled by using the following notations [3],

a) LLn represents the approximation image nth level decomposition, resulting from low-pass filtering in the vertical and horizontal both directions.

b) LHn represents the horizontal details at nth level of decomposition and obtained from horizontal low and vertical high-pass filtering.

c) HLn represents the extracted vertical details/edges, at nth level of decomposition and obtained from vertical low pass filtering and horizontal high-pass filtering.

d) HHn represents the diagonal details at nth level of decomposition and obtained from high pass filtering in both directions.
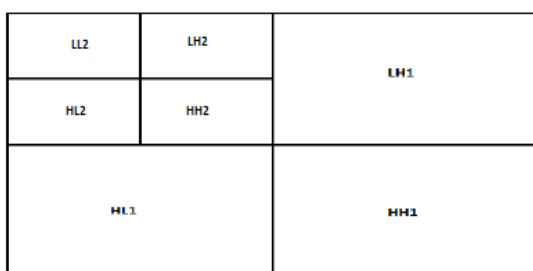

Figure 2.1.3: Image decomposition

B. HaarWavelet[1]
Properties of Haar wavelet transform:

1. Haar Transform is real and orthogonal. Therefore
$Hr = Hr^*$ (1)
$Hr = Hr$ (2)
Haar Transform is a very fast transform.

2. Orthogonality: The original signal is split into a low and a high frequency part and filters enabling the splitting without duplicating information are said to be orthogonal.

3. Linear Phase: To obtain linear phase, symmetric filters would have to be used.

4. Compact support: The magnitude response of the filter should be exactly zero outside the frequency range covered by the transform. If this property is algebra satisfied, the transform is energy invariant.

5. Perfect reconstruction: If the input signal is transformed and inversely transformed using a set of weighted basis functions and the reproduced sample values are identical to those of the input signal, the transform is said to have the perfect reconstruction property. If, in addition no information redundancy is present in the sampled signal, the wavelet transform is, as stated above, orthonormal.

The advantages of Haar Wavelet transform as follows:

1. Best performance in terms of computation time[1].

2. Computation speed is high. Called lossless compression.

3. Simplicity (e.g., if, = 0).

4. HWT is efficient compression method.

5. It is memory efficient, since it can be calculated in place without a temporary array.

C. Neural Network
Neural network is a computational or mathematical model based on biological neural networks[3]. It finds the application in the field of image processing, it is technique for image compression due to parallelism learning capabilities, noise
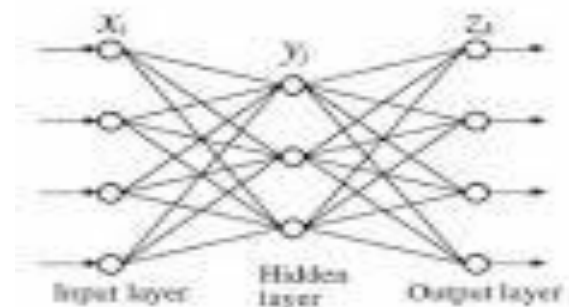

Figure 2.2.1: basic neural network topology

suppression, transform extraction and optimized approximations. It consist of a inter-connected group of artificial neurons and processes the information using a connectionist approach to computation.A neural network is a non-linear system. Feed forward is a simplest neural network architecture. It consists of three layers: 1. Input layer 2. Hidden layer 3.Output layer. In this type of

architecture input from large number of neurons is fed to less number of neurons, which is further fed to large number of neurons in the output layer of the network. The number of connections between any two layers in the neural network can be calculated by multiplying the total number of neurons of the two layers then adding the number of bias neurons connections of the second layer.

D. Levenberg Marquardt Algorithm

This algorithm is well suited for image compression, as it pre-processes input pattern to compressed patterns giving rise to sufficient compression rates and preserving the information security. Different types of algorithms for training the neural networks, like back propagation, scaled conjugate gradient, resilient back propagation etc. In our paper, we are using the LM algorithm for image compression, in addition to DWT, DPCM, Quantization and Huffman coding etc. Levenberg Marquardt algorithm[4] is also called as back propagation algorithm. It is a common training method based on error correction learning rule. Error is propagated in both forward and backward direction propagated through the layer of the network. In forward pass the inputs are applied to the nodes of the network and the effect passes through the network layer by layer giving an output response, in the forward direction the weights of the network will be fixed, bur in the backward direction weights are adjusted according to error correction rule. Training involve iterative updating of weights to minimize the mean square error.
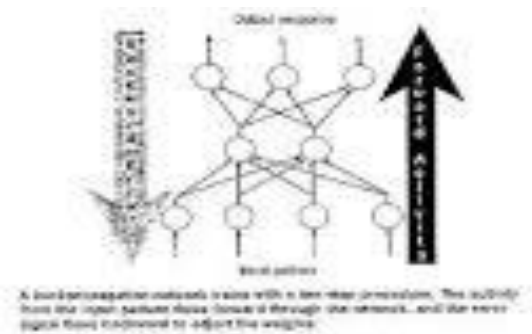

Figure 2.2.2: back propagation network
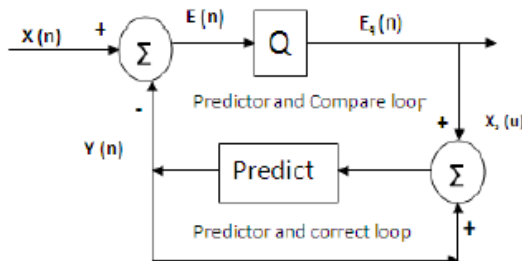
III. DIFFERENTIAL PULSE CODE MODULATION

Fig 3.1: Block diagram of DPCM

Differential pulse-code modulation (DPCM)[4] is a signal encoder that uses the baseline of pulse-code modulation (PCM) but adds some functionality based on the prediction

of the samples of the signal. The input can be an analog signal or a digital signal.

If the input is an analog signal, it needs to be sampled first so that a discrete-time signal is the input to the DPCM encoder.

- Option 1: take the values of two consecutive samples; if they are analog samples, quantize them; calculate the difference between the first one and the next; the input is the difference, and it can be further entropy coded.
- Option 2: instead of taking a difference relative to a previous input sample, take the difference relative to the output of a local model of the decoder process; in this option, the difference can be quantized, which allows a good way to incorporate a controlled loss in the encoding.

Applying one of these two processes, short-term redundancy (positive correlation of nearby values) of the signal is eliminated; compression ratios on the order of 2 to 4 can be achieved if differences are subsequently entropy coded, because the entropy of the difference signal is much smaller than that of the original discrete signal treated as independent samples. The block diagram of the DPCM is as shown in fig 3.1.

IV. HUFFMAN CODING

Huffman coding is an entropy encodingalgorithm used for lossless data compression.Huffman code procedure is based on the twoobservations:

a. More frequently occurred symbols will have shorter code words than symbol that occur less frequently.

b. The two symbols that occur least frequently will have the same length.
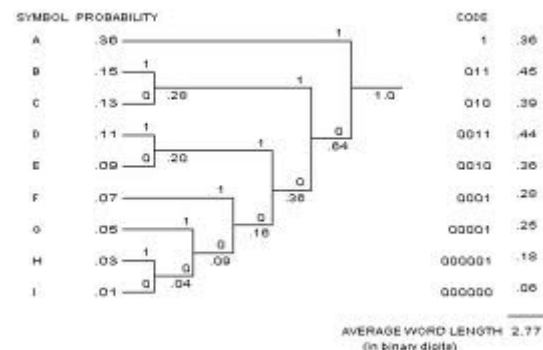
The Huffman coding is shown in the figure 4.1.

Fig 4.1: Process of Huffman coding
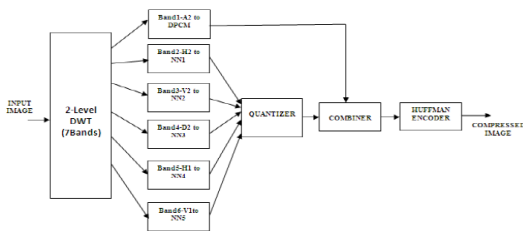
V. PROPOSED BLOCK DIAGRAM

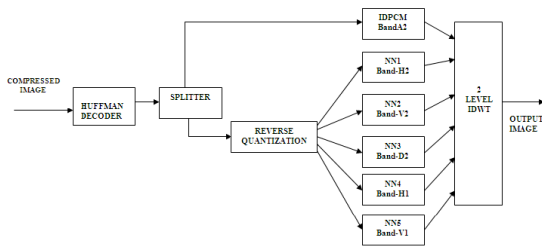Fig 5.1: Block diagram for image compression

Fig 5.2: Block diagram for image decompression

The block diagram of image compression is as shown in the fig 5.1[4]. The process is as explained below. HAAR wavelet transformation undergoes two level decomposition, low frequency and high frequency. Low frequency components are the compressed using DPCM encoder and high frequency components are compressed using a neural network. The low frequency band-1 is compressed with Optimal DPCM which reduces the inter pixel redundancy. Depending upon previous pixel information we can predict the next pixel,the difference between current pixel and predicted pixel is given to optimal quantizer which reduces the granular noiseand slop over lode noise. These error values are scalar quantized. The Human Visual System (HVS) issensitive to different frequency components,hence neural network is preferred, resulting in different compression ratios for the various frequency bands. After the wavelet coefficient are compressed using eitherDPCM or by using neural network. The output of the DPCM and neural network are scalar quantized where the values ofentire kx1 hidden vectors are scalar quantized at once. Finally, the quantized values are Huffman encoded and the results are obtained. Reverse process is carried out in the decompression process to get back the reconstructed image as shown in the fig 5.2.

CONCLUSION

Different hybrid image compression methodologies like Wavelet transforms, DPCM, Neural networks, quantization and Huffman encoding etc are used for compression and decompression images.Wavele decomposition eliminates blocking effects associated with DCTWavelet transform based decomposition improved the quality of reconstructed images when compared to the neural networks applied for compression on the original image. This work may be further extended for automatic compression of data and images to a large extent where transfer of data over web is most effective and convenient for the users. In this proposed methodology of image compression data can be assumed to be secured and will not lose its efficiency. Moreover it can be used in Bar code creation to identify any product or person and can also be used in various fields like space, medical, defence and many more.

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