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Advancement of Neuro-Wavelet Network over Neural Network in Image Compression

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Abstract: As the complete world is digitizing, demand for the bandwidth is also increasing in the same proportion. So image compression is a very important factor for storage and transmission of image/data. Nowadays, in modern technical era, hybrid coding based compression system has became more popular as compared to traditional methods because of its special feature to include the advantages of individual techniques without losing the quality of image/data at high compression ratio. If Wavelet-based image compression is used for compression, the good picture quality can be retrieved and also achieves better compression ratio. Also in the past few years Artificial Neural Network becomes popular in the field of image compression. This paper presents a review report based on neuro-wavelet model which provides practical and effective image compression system. A Neuro-Wavelet model combines the advantages of multiresolution capability of wavelet transform scheme with neural network, which has the ability to reproduce the original data with the help of available fewer components.

Keywords: ANN;Hybrid Coding; Neural Network; Vector Quantization; Neuro-Wavelet Network.

I. INTRODUCTION

Transmission of digital image over communication channels is time consuming and requires a large amount of data for its presentation. This may not be affordable in terms of time, cost in various cases. So in order to store the images in less memory space as well as make it suitable for transmission within few seconds/minutes, compression of image data is essential. The compact representation of an image while maintaining all the necessary information without much loss of data is referred to as Image compression. It is basically a redundancy reduction technique. This reduction helps in increasing the capacity of storage and efficient transmission. Image compression schemes [1] are generally classified as lossless compression schemes and lossy compression schemes. Lossless compression is an error free compression where the original data can be recovered after decompression. This scheme provides low compression ratio but has several applications, like in the compression of medical images and documents where the loss of information are not acceptable. In lossy compression, during decompression process, an approximation of original data is obtained, because some extend of the original data is lost during compression. As compare to lossless schemes, lossy schemes achieves higher compression ratio and are used in applications, like compression of natural images where perfect reconstruction is not essential and it can afford the partial loss in the image data as long as it is within tolerance. This paper focuses on the combined approach of image compression using neural networks and wavelet transforms, called the neuro-wavelet approach. Combination of Neural network and wavelet transform is a successful, effective, efficient, secure, and widely used compression technique over the years. Our purpose is to discuss an artificial neural network and more especially a wavelet network. Neural networks can be trained to represent certain sets of data. After decomposing an image using the discrete wavelet transforms (DWT), a neural network may be able to represent the DWT coefficients in less space than the coefficients themselves. Over the last decade, numerous attempts have been made to apply artificial neural networks.

II. ARTIFICIAL NEURAL NETWORK

An artificial neural network (ANN), often just called a "neural network" (NN), is a mathematical model or computational model based on biological neural networks. It consists of an interconnected group of artificial neurons and processes information using a connectionist approach to computation. In most cases an ANN is an adaptive system that changes its structure based on external or internal information that flows through the network during the learning phase. Figure 1shows a neural network architecture which can be used for image compression. As shown in the diagram, large numbers of input neurons are used to feed the information to the less number of hidden layer neurons, which is further applied to output layer of the network having large number of neurons. Since the information is flowing in the forward direction, such type of network is known as feed forward network .One of the most important types of feed forward network is the multilayer back propagation neural network [9, 10].

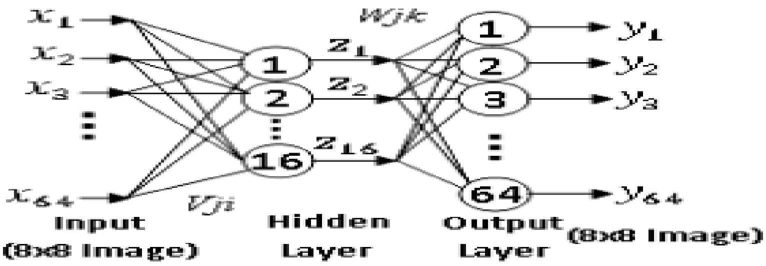

Fig.1.Feed Forward neural Network

In recent years, the application of artificial neural network (ANN) in the field of image processing has been increased. An Artificial Neural network is appropriate technique for image compression due to parallelism, learning capabilities, noise suppression, transform extraction, and optimized approximations.

III. WAVELET TRANSFORM

A wavelet is a wave-like oscillation with an amplitude that starts out at zero (0), increases, and then decreases back to zero [2]. Wavelets have special features such as convolution, multiresolution ,which can be used to extract information from the unknown signal.

a) Continuous Wavelet Transforms (Continuous Shift and Scale Parameters)

A continuous-time function can be divided into waveletsby using continuous wavelet transform (CWT).It offers very good time and frequency localization in time frequency domain. Mathematically, continuous wavelet transform can be represented as of a x(t) and is expressed by the following integral,

$$X_a(a,b) = \frac{1}{\sqrt{|a|}} \int_{-\infty}^{\infty} x(t)\varphi^{*}\left(\frac{t-b}{a}\right) dt \qquad (1)$$

where, x(t) is a continuous, square-integrable function at a scale a>0 , b is a translational value where b € R and Ψ(t) is a continuous function in both the time domain and the frequency domain called the mother wavelet. To recover the original signal x(t), inverse continuous wavelet transform can be exploited ,as shown in equation 2,

$$x(t) = \int_{0}^{\infty} \frac{1}{a^2} X_a(a,b) \frac{1}{\sqrt{|a|}} \int_{-\infty}^{\infty} \varphi^{-}\left(\frac{t-b}{a}\right) db\, da \qquad (2)$$

where, Ψis the dual function of Ψ(t).

b) Discrete Wavelet Transforms (Discrete Shift and Scale Parameters)

In DWT, an image is represented by sum of wavelet functions, having different location and scale.Fig.2 shows wavelet filter decomposition. For a given level n, the sub-bands are labelled by using the below notations [3],

1. LLn represents the approximation image nth level of decomposition, resulting from low-pass filtering in the vertical and horizontal both directions.
2. LHn represents the horizontal details at nth level of decomposition and obtained from horizontal low-pass filtering and vertical high-pass filtering.
3. HLn represents the extracted vertical details/edges, at nth level of decomposition and obtained from vertical low-pass filtering and horizontal high-pass filtering.
4. HHn represents the diagonal details at nth level of decomposition and obtained from high-pass filtering in both directions.

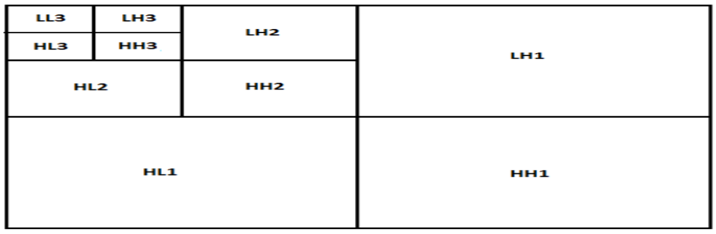

Fig.2.Wavelet Filter Decomposition

The Discrete Wavelet Transform (DWT) based coding, has been emerged as another efficient tool for image compression [4-6] mainly due to its ability to display image at different resolutions and achieve higher compression ratio.

IV. Literature Survey

Amar et al. in [9] presented a wavelet networks approach for image compression. The wavelet network is a combination of wavelets and neural networks. It can be understood as a combination of radial basis function (RBF) networks and wavelet decomposition, where radial basis functions were replaced by wavelets. Proposed wavelet network and the neural network, both are same in the sense that both networks calculate a linear combination of nonlinear functions to adjust parameters. They have compared this approach with some other approaches based on neural networks (MLP), and found it more robust.

Singh et al. in [7] has used neuro-Wavelet based approach for image compression. In this paper a neuro-wavelet based model has been proposed in which advantages of both techniques has been utilized. Firstly the mage is decomposed using wavelet transform into a set of subbands corresponding to different frequency bands. Further based on their statistical properties, there are different coding schemes for different sub bands. The differential pulse code modulation (DPCM) is used for low frequency band coefficients and the higher frequency bands coefficients via neural network. Their proposed scheme results in a large compression ratio with satisfactory reconstructed images.

A novel method to image compression using neural networks is proposed in [11] by Adnan et al, in which Haar compression is used with nine compression ratios along with supervised neural network. Because of the lossy characteristics of Haar wavelet compression, the compressed image's quality degrades at higher compression ratios. Two neural networks; namely ANN32 and ANN64 with 100 images having various features have been taken to implement the proposed system. They have suggested the implementation using bi-orthogonal wavelet transform replacing Haar wavelet and comparing the performance of both.

V. Proposed Method

a) Image Compression Using ANN

As the preparation of image compression, there are some steps have been followed .These steps are as follows:-

STEP1. First, image segmentation is necessary that means segment the image into a set of m blocks l by l pixels and reshaping each one into column vectors.

STEP2. In this step we arrange all column vectors in a matrix. The m blocks of subimages are applied as inputs for the neural networks.

STEP3. Then a three layer neural network is used, an input layer with M neurons with l by l pixels an output layer with N neurons (here N=M) and a hidden layer with K number of neurons, K is always smaller than M ; (K<M) and it is based on activation functions.

STEP4. Neural network is trained in order to reproduce the information given by input layer in output layer.

STEP5. Simulation of network by using input data, result matrices and an initial error value.

STEP6. Reconstruction of the original image

STEP7. Terminate the calculation of error is smaller than threshold.

b) Image Compression UsingNeuro-Wavelet Network

The flow chart summarizes the whole process of image compression using Neuro-Wavelet network.

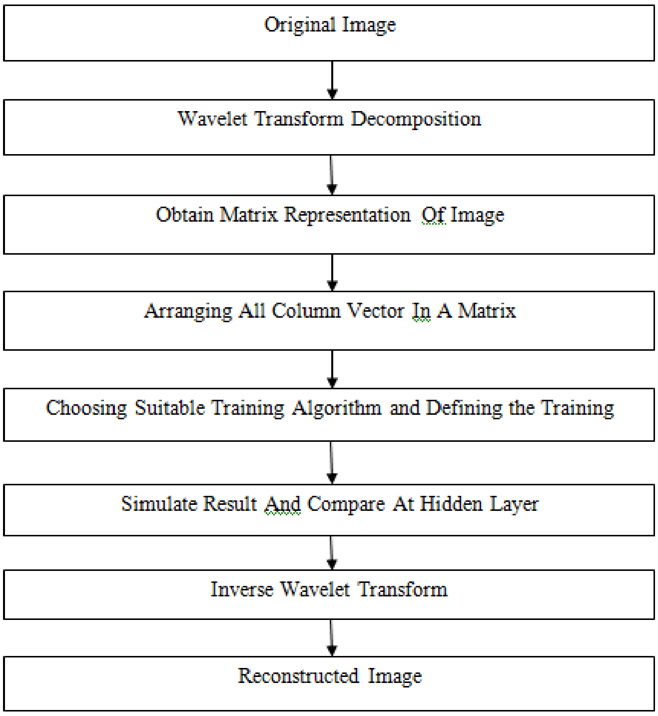

Fig.3.Flow Chart of Neuro- Wavelet Network Process

VI. EXPERIMENTAL RESULT

The internal memory is 2G of the computer which used in this experiment. The operating system is Window 7. The calculative software is Matlab R2010a.In order to keep the objectivity of this experiment; we set the same training conditions for neural network (multi-layer perceptrons) and neuro-wavelets as TABLE1.

Since, it is always required to minimise the distortion and loss in the reconstructed image. But for any compression methods, some elements will lose during the compression process. To evaluate the compressed methods' performance, two standards are used; one is peak signal to noise ratio (PSNR) and another is mean square error (MSE). It is obvious that larger the MSE, the worst the compressed performance is. Also larger the PSNR, the better the compressed performance is. Under the same training conditions mentioned above, this paper adopts multilayer perceptrons and wavelet networks to compress images at different compression ratios.

The definition of these parameters is as follows

$$\mathrm{MSE} = \frac{1}{\mathrm{M} \times \mathrm{N}} \sum_{\mathrm{i}=0}^{\mathrm{M}-1} \sum_{\mathrm{J}=0}^{\mathrm{N}-1} \left(\mathrm{F}(\mathrm{i},\mathrm{j}) - f(i,j)\right)^2 \quad (3)$$

$$\mathrm{PSNR} = 10 \log_{10} \frac{1}{\mathrm{NMSE}} \quad (4)$$

where, F represents original image of size M × N and f is the reconstructed image of same size.

TABLE I. TRAINING CONDITIONS

Image dimensions	512×512
Block size	8×8
Training algorithm	Gradient descent
Level of WT	2- level WT
Types of Wavelet used	Haar wavelet
Input and Output(M=N)	64
Maximum iteration	1000
Learning rate	10^{-10}

a) Comparison between Multi-layer Perceptrons and Wavelet Networks

Firstly, the experimental results of neural network (MLP) and neuro-wavelet networks are compared. The hidden layer's activation function is sigmoid function and output layer is purely linear function. For the neuro- wavelet network, we use HAAR wavelet and pure linear function in the output layer. The gained results of BARBARA image experiment are shown in TABLE II and TABLE III.

From TABLE II and TABLE III, we can get the following analysis results. The rough whole tendency for both neural network (MLP) and neuro-wavelet network used in image compression is that higher the compression ratio, smaller the value of PSNR. So as long as we set the proper size of the hidden layer in neural networks we can get less distortion in the reconstructed images. We can deduce that the performance of the neuro-wavelet network is better than that of neural network (MLP) in image compression.

b) Comparison between Different Kind of wavelet Networks

The following task is comparing the compression performance among different types of wavelet networks. The activation functions are HAAR wavelet transform in hidden layer of neuro-wavelet networks. The activation functions in output layer are pure linear function in both kinds of neuro-wavelet networks. The results of BARBARA image are depicted in TABLE II.

Also the PSNRs are different in different kinds of neuro- wavelet networks (activation functions in hidden layer are HAAR wavelet transform). Also the higher compression ratio is, the smaller the value of PSNR is.

c) *Result Analysis*

From TABLE II , figures 4,5 we can find that: (1) the performance of neuro-wavelet network is better than that of neural network (MLP) in the same situation, (2) the higher compression ratio is, the smaller the value of PSNR is, (3) the PSNRs are different from other kind of neuro-wavelet networks,

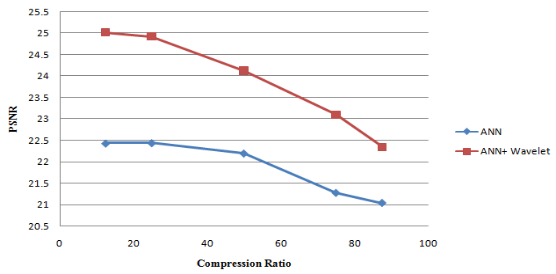

Fig.4.PSNR Vs. Compression ratio for BARBARA image

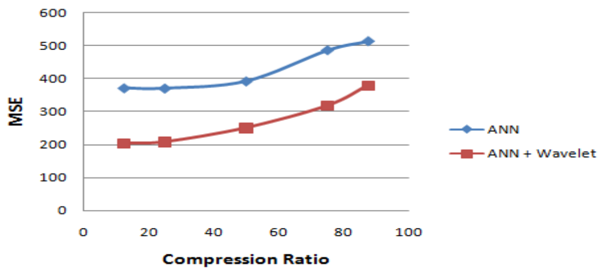

Fig.5. MSE Vs. Compression ratio for BARBARA image

TABLE II.BARBARA Image Compression by Neuro-wavelet network & Neural Network (MLP)

IMAGE COMPRESSION BY NEURO WAVELET NETWORK			IMAGE COMPRESSION BY MLP CLASSICAL APPROACH		
CR	PSNR (dB)	MSE	CR	PSNR (dB)	MSE
12.5%	25.0236	204.5125	12.5%	22.4310	371.5165
25%	24.9295	208.9933	25%	22.4202	373.7344
50%	24.1294	251.2717	50%	22.1959	392.1808
75%	23.1055	318.0732	75%	21.2675	485.6583

In fact, the experiment results are different from each experiment because of the randomicity of initializations. It is necessary to do the following things: (1) research new training algorithm such as adaptive algorithm, momentum algorithm etc. And combine them together, (2) set proper limits to every parameters, (3) find proper compressed ratio (the size of hidden layer), (4) find proper wavelet which works as activation function in image compression.

VII. Conclusion

At first the fundamental theory of artificial neural network (ANN) and wavelet theory with wavelet transformation have reviewed. Then this paper expresses the training algorithm for multi-layer perceptron (MLP) and multi-layer perceptron with wavelet coefficients. At last this paper gives number of experimental results. The results include two different kinds of neural networks act on different images under different compression rates. From these different results we got conclusion that, neuro wavelet network achieve better effect on image compression as compare to MLP (multi-layer perceptron. This algorithm has flexibility in the sense that we can improve compression ratio as per our requirement by increasing the number of hidden neurons. The reconstruction quality can be improved by increasing the iterations. Another positive feedback have been obtained that the PSNR value is good and have very less variation as increasing compression rates from 25% to 87.5.

We have used grayscale image for our experimental results, so these techniques are can be used for colored images which include color image processing. Also future work is to develop new training methods, proper size of hidden layer and also it has very vast scope, by developing different kinds of wavelet neural networks. There are so many different kinds of ANN functions for activation can be used. Different wavelets can be applied to improve compression efficiency.

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