IOSR Journal of Electronics and Communication Engineering (IOSR-JECE)
e-ISSN: 2278-2834,p- ISSN: 2278-8735
PP 23-29
www.iosrjournals.org

A Review on Emerging Techniques in Digital Image Compression

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Abstract: *Image compression is basically a process of encoding the image to trim down the size of image as a number of bytes for storage and transmission purposes, while maintaining as much as possible the quality of the image. The quality of the image of most importance in any compression technique with a good compression ratio. The compressed image requires less memory space and less transmission time. A number of techniques have been developed in image processing. This paper gives a detailed view of Lossy and Lossless compression techniques and also the architectures of most efficient transforms such as Discrete Wavelet Transform (DWT) and Neural Networks and the newly developed Artificial Neural Network and Fuzzy Inference System (ANFIS) that can be efficiently used for image compression. This paper also gives a review on a hybrid method for image compression using wavelet and Artificial Neural Network and Fuzzy Inference System (ANFIS).*
Keywords: *Artificial Neural Networks (ANN), Artificial Neural Network and Fuzzy Inference System (ANFIS), Differential Pulse Code Modulation (DPCM), Discrete Wavelet Transform (DWT).*

I. Introduction

Image compression is the application of data compression on digital images. It plays an important role in many applications including communication and medical field. The main objective of this technique is to reduce the redundancy of the image pixels in the suitable form of storage media or transmit data in a competent form. Basically there are two types of image compression. Lossless compression, where the compressed image is totally replica of the original input image, there is no amount of loss present in the image. It is preferred for archival purposes and often for medical imaging, technical drawings etc. In Lossy compression there is some amount of loss from the original image. It is used widely at low bit rates, discards some of the data so that it becomes simplified enough to be stored within the desired disk space or to transmit within the band width (BW) limitations [1].

Lossless compression techniques reconstruct an image which is same as the original image. This technique first converts the images into image pixel, where processing is carried out on each pixel. The first stage includes prediction of next image pixel value from the neighbourhood pixel and second stage calculates the difference between predicted value and the actual intensity of the next pixel which is coded using different encoding methods.

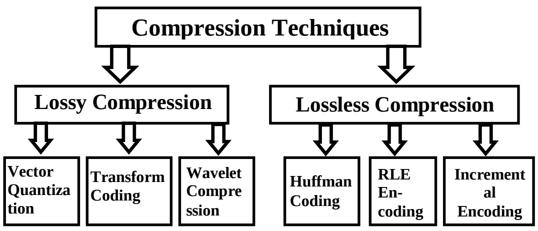


Fig 1 Compression techniques

Lossy compression technique ensures high compression ratio than Lossless compression techniques. This technique produces imperceptible differences and is also referred as visually lossless. Vector quantisation, transformation coding and wavelet compression methods are widely used Lossy compression techniques.

Transformation coding employs coding schemes like Discrete Fourier Transforms (DFT) and Discrete Cosine Transforms (DCT) to change the pixel in the original image into frequency domain coefficients. This technique has the advantage of low BW requirements.

Wavelet compression analyses the image in a recursive fashion which results in a series of higher resolution images. The main steps involved in wavelet compression method are to perform DWT, quantization of the wavelet space image sub-band and then encoding these sub-bands where compression occurs.

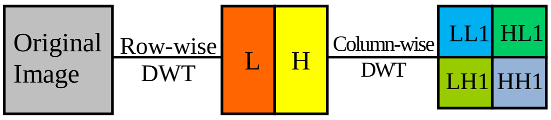
Decompression can be achieved by inverse process steps like decode, de-quantize and inverse DWT [2][3]. This paper discusses various image compression methods and also a hybrid method combining wavelets and neural network with fuzzy inference systems. Methods and architectures are explained briefly below.

II. Image Compression Using Dwt

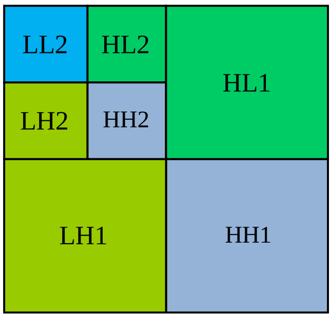
Wavelets are a mathematical tool for hierarchically decomposing function in multiple hierarchical sub-bands with timescale resolution. Wavelet transform is a powerful image compression method to get compressed images with high PSNR values and high compression ratios. Wavelet transforms unlike DCT method, do a better job of handling discontinuities in data [4][5][6].

1. Architecture of DWT

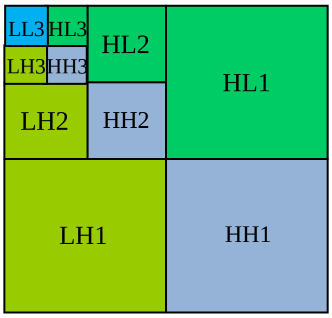
DWT is an effective wavelet transform method which is based on sub-band coding. It is a fast computation method and can be implemented easily. In case of DWT timescale representation of the digital signal is obtained using digital filtering method. Signal to be analysed, is passed through filters with different cut off frequencies at different scale.



(a) First level Decomposition



(b) Second level Decomposition



(c) Third level Decomposition

Fig 2. Row-column computation of 2-D DWT

In DWT image compression, the input image is decomposed into high pass and low pass components using filter sections (HPF and LPF) which gives rise to first level decomposition. In this level, four possible combinations, such as LL, LH, HL and HH are obtained. Further, the LL sub-band is decomposed into four more sub-bands as shown in the figure above, which gives rise to the second level decomposition. The LL sub-band is more significant as it contains more information of the original image and the higher order sub-bands contain the edges in the vertical, horizontal and diagonal directions. Further, the third level of decomposition can be obtained by decomposing of the LL2 band as shown above. Second and third level DWT gives the better compression ratio with loss of some information. HAAR DWT algorithm can be used for this decomposition. Simulation can be done using MATLAB Code.

III. Image Compression Using Neural Network (Nn)

Artificial neural network (ANN) is a biologically inspired computation model which consists of processing elements called neurons. They are also referred as connectionist model. Connection weights are memory of the system. Neural networks are configured for a particular application through learning process. Learning in biological systems includes adjustment of weights. Various learning algorithms can be employed based on the neural networks used. Neural networks have been successfully applied to broad spectrum of data intensive applications. [3]

Neural networks is a recent tool in image compression which employs parallel processing of data and hence requires less computation time. They are inherent adaptive systems which are suitable for handling non-stationeries in image data. In this section NN architecture for image compression based on back propagation neural network is discussed [7][8].

Image compression can be achieved by using multi-layer NN. The network parameters will be adjusted using different learning rules for the purpose of comparison.

1. Architecture of NN

Image compression application widely uses multi-layer feed forward NN which consists of one input layer, one output layer and a number of hidden layers. Each layer consists of a number of neurons or nodes. For image compression, a two layer structure as shown in the figure below can be used.

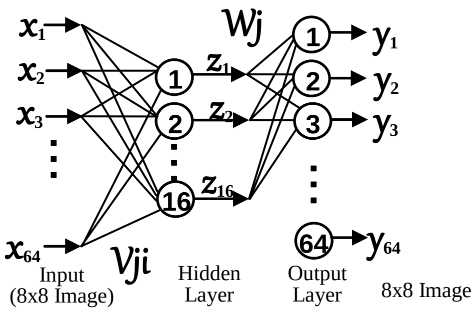


Fig 3. Bottleneck Feed Forward NN

The number of neurons in the hidden layers is selected to be less than the number of neurons in the input and output layers. Compression occurs at the hidden layers. Such types of NN are also referred as bottleneck type feed forward NN. One of the most important types of feed forward network is multilayer back propagation neural network. The Levenberg-Marquardt (LM) algorithm with back propagation NN can be used to obtain image compression. Simulation can be done using MATLAB Code [9].

IV. Iv. Image Compression Using Artificial Neural Network And Fuzzy Inference System (Anfis)

A new method using an adaptive neuro fuzzy inference system or adaptive network based fuzzy inference system (ANFIS) is a kind of artificial neural network that is based on Takagi-Sugeno fuzzy inference. It integrates both neural networks and fuzzy logic principles ie. it captures the benefits of both in a single framework. The main problems while using fuzzy system is when we apply _if-then' rules to fuzzy system it takes more time for evaluation also a fuzzy set is fully determined by its membership function. For a given input/output data set, the function ANFIS constructs a fuzzy inference system (FIS) whose membership function parameters are adjusted using either a back propagation algorithm or back propagation in combination using the method of least squares. This will allow the fuzzy systems to learn from the data they are modeling. The ANFIS approach learns the rules and membership functions from data. ANFIS is an adaptive network consists of network of nodes and directional links [10][11]. Associated with the network is a learning rule - for example back propagation. The name adaptive come from the fact that here some or all, of the nodes have parameters which affect the output of the node. These networks are useful for learning a relationship between inputs and outputs.

1. Architecture of Adaptive Neuro-Fuzzy Inference system (ANFIS).
Architecture of ANFIS for a two rule Sugeno system is shown in figure 4 below.

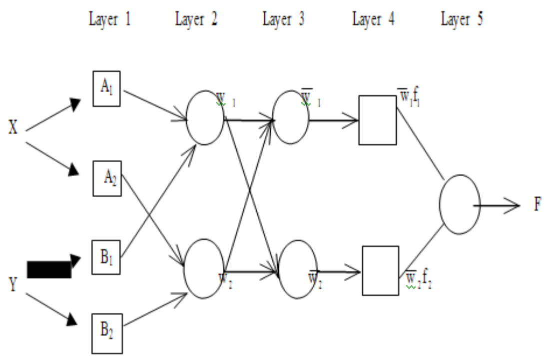


Fig 4. Two level ANFIS structure.

In ANFIS both forward and a backward pass is used for the training of the network, here the input vector is propagated through the network layer by layer in forward pass while, in the backward pass, similar to the back propagation only the error is sent back in the network . In this paper, as in back propagation neural networks, ANFIS network is trained using back propagation algorithm for training the data set. Compression is done in three steps i.e. first the data set for various frequency bands after decomposition is trained by proper setting of error tolerance and epochs. In order to minimize the error we set epochs to 100 and error to 0. Second step is to test the data set by loading data from workspace and finally generate fuzzy inference system. After generating a FIS file will be generated which will then applied to quantizer for further compression via k- means algorithm. Quantization is a compression technique achieved by compressing a range of values to a single quantum value. In quantization, a signal is mapped into a series of k discrete messages. The optimal thresholds are equidistant from the values, for a given set of quantization values. The concept of quantizing data can be extended from scalar or one dimensional data to vector data of any arbitrary dimension. Vector Quantization employs a set of representation vectors (for one dimensional cases) or matrices for two dimensional cases. The set therefore is referred as codebook and entries as code-words. The k- means clustering is used since it can easily be used to choose k different but prototypical objects from a large data set for further compression.

V. Hybrid Method For Image Compression

Image compression using wavelet in combination with Artificial Neural network and Fuzzy inference system (ANFIS) are used in this method so that we can achieve better compression. Figure 5 below shows the complete image compression system.

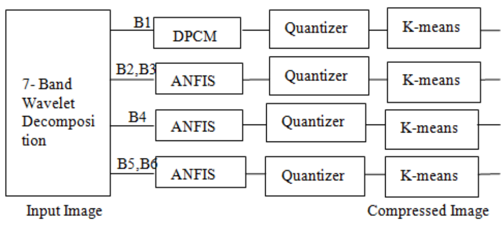


Fig 5 Complete Image Compression

In this METHOD, the input image is first decomposed using seven band wavelet decomposition. On decomposition we get seven different bands each of with different frequency and characteristics. Since most of the information is in lowest frequency band i.e.B1, it is encoded with Differential pulse code modulation (DPCM) [12]. After this the coefficient are scalar quantized. The remaining frequency bands are coded using Adaptive Neural Fuzzy Inference System (ANFIS). The information of Band 7 is discarded as it contains little information to contribute to the image from the stand that this band can be assumed to be zero with little effect on the quality of reconstructed image. The output of Artificial Neural network and Fuzzy inference system (ANFIS) is then quantized. Finally these quantized values are subjected to k-means to achieve further compressions.

1. 7-Band Wavelet Decomposition.

The first step is to decompose the input image into 7 sub bands using wavelet decomposition. As most of useful frequency contents are in band 1, it is encoded using DPCM, Bands 2 and 3 contain the same frequency contents for different orientations therefore both the bands are quantize separately using ANFIS also the frequency contents for bands 5 and 6 are same thus these bands are quantize with another quantizer via ANFIS structure. The coefficients of Band-4 are different thus it is coded using separate quantizer. Since Band-7 contains less information thus it is discarded. The output of the ANFIS network is then quantized [13]. Finally these quantized values are applied to K-means clustering for achieving better compression.

2. Differential Pulse code Modulation (DPCM).

Differential Pulse Code Modulation (DPCM) is a method of converting analog signal into digital signal where the analog signal is sampled and then difference between actual sample value and its predicted value is quantized and then encoded forming digital value. DPCM is form of predictive coding because it is necessary to predict sample value. Image compression using DPCM depends on prediction technique since well-conducted prediction techniques leads to good compression rates [14][15]. DPCM encoder is shown in Figure 6, it is the combination of quantizer, entropy enceoder and a predicator.

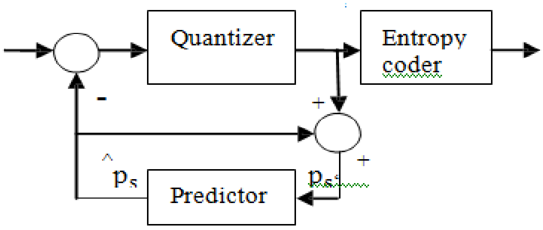


Fig 6. DPCM Encoder

Here p_s is the current sample and $\hat{}p_s$ is predicted value, $\hat{}p_s$ is formed using prediction factors and previous samples, for this linear prediction is used, thus predicted value can be given as a weighed linear combination of ‗m‘ previous samples using x_i, weighting factors:

We choose weighting factors

$$x_i \,\hat{}p_s = p_s(i) \quad (1)$$

Then the difference in signal is given by:

$$v = p_s - \hat{}p_s = p_s(i) \quad (2)$$

In order to minimize some function of error between p_s and $\hat{}p_s$ (like mean-squared) this leads us to minimization of quantization noise (better signal-to-noise ratio). In this paper we use DPCM because it gives image with a continuous-tone which mostly contains smooth tone transitions. Also using DPCM we can assign short code words to achieve a good compression ratio [16].

VI. Performance Evaluation

Performance of each image compression method can be measured by evaluating the Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR) values [8]. The quality of image is also very much important in any compression technique. MSE between the original image and compressed image should be as small as possible so that the quality of compressed image should be near to that of the original image ie. it should resemble the original image. This parameter can be evaluated as

$$MSE = \frac{1}{mn} \sum_{y=1}^{m} \sum_{y=1}^{n} [I(x,y)-I'(x,y)]^2 \quad (3)$$

where m and n are the number of rows and columns in the input image, I (x,y) corresponds to image values of original image and I'(x,y) corresponds to image values of compressed image. Thus MSE can be defined as the cumulative difference between the compressed image and the original image. PSNR also defines the quality of the image. It depends on the maximum value of pixels of an image and MSE. PSNR can be evaluated as

$$PSNR(dB) = 10\log_{10}\left(\frac{L^2}{MSE}\right)dB \quad (4)$$

where L is the maximum value of pixels of an image. The higher the value of PSNR means better the quality of the image, or otherwise higher value of PSNR can be obtained only if error (MSE) is less.

Another parameter related to performance of image compression is the Compression Ratio (CR). It can be expressed as

$$CR = \frac{\text{Original Image Size}}{\text{Compressed Image Size}} \quad (5)$$

CR is a quantitative measure and can be used to measure the capacity of image data compression by comparing size of original image against compressed image.

VII. Related Works

Vilas H Gaidhane and Vijender Singh (2011) describes NN with bottleneck type feed forward back propagation network for image compression. In this paper, bipolar coding technique and LM technique are proposed and implemented. Further, these techniques are compared with Principal Component Analysis (PCA) technique. Experimental evaluation was carried out on standard 256 x 256 pixel Leena and 32 x 32 Lussy images. These input images are converted into 8 x 8 pixel and experimented with various number of neurons in the hidden layers. It was observed from the experimental results that the image compression using LM algorithm performs better than the PCA and Bipolar Coding and has more convergent speed. This algorithm suits the best for small and large image compression and requires less memory to store the results.

Birendra Kumar Patel (2013) describes NN training process as the best for image compression and its applications. In this paper, back propagation NN with LM algorithm is proposed and implemented. Simulation is done using MATLAB Software. Results shows that compression and convergence time can be improved using this technique. Simulation results for 64 x 64 pixel images are shown and performance measure graph are also included.

Pravin.B. Pokle and, Dr. Narendra.G. Bawane(2014), has described a novel technique for image compression in their work using ANFIS in Wavelet Domain for that better compression ratio with minimum error. The overall implementation of the work is done in four steps:First, seven band wavelet. Based upon statistical properties of sub bands, different quantization and coding schemes are used. Second, first sub band is compressed using differential pulse code modulation (DPCM), the coefficient corresponding to other sub bands are compressed using Adaptive Neural Fuzzy Inference system (ANFIS). In the third stage, the result obtained is fed as input to the fuzzy vector quantizer and in fourth stage the output obtained from third stage is fed to the K means quantizer for further compression. Finally the results are compared for MSE, PSNR and the visual appearance after decoding of image.

Vinit D Raut (2015) presents a new approach for image compression with efficient transforms and multistage vector quantization (MSVQ). This work utilises image compression in transform domain with 2D-DWT. Huffman Coding is used to encode the indices generated from MSVQ and low frequency sub-band generated from DWT. Codebook generation is done using LBG algorithm with Radial Basis Function (RBF) neural network. The proposed method uses two stages of vector quantization. In this approach, the input image is applied to a two dimensional DWT using first level of decomposition to generate four sub-band images using a HAAR filter. Implementation is done using MATLAB 2012 on core 15 processor. Different transforms such as 2D-DWT, DCT and 2D-DCT were performed on six different types of images of size 128 x 128 pixel. The Mean Square Error (MSE) & PSNR value are calculated and image compression efficiency is evaluated based on bit rate and compression ratio obtained. Experimental results prove that 2D-DWT gives better compression than other transform methods. This paper suggests to work on more decomposition levels of wavelet transforms along with other neural network techniques.

VIII. Conclusion And Future Work

This paper defines image compression and the various techniques that can be used for compression. Advanced compression methods using wavelet transforms, neural network and neural networks and fuzzy inference systems are explained in detail. Implementation of all the methods can be realised using various algorithms and simulation can be carried out usings MATLAB. For future work this hybrid method combining both the wavelet transform method and ANFIS compression algorithms can be implemented and better results can be obtained for the various performance parameters.

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