Image Compression Using Improved Wavelet Shrinkage and Artificial Neural Network

Seyed Mahmoud. Anisheh, and Davood. Asemani

Abstract— This paper presents a novel approach for image compression using improved wavelet shrinkage method in combination with artificial neural networks. In the proposed method, a new method for choosing threshold value of wavelet shrinkage technique is presented by cuckoo optimization algorithm. In the second step, an artificial neural network is used as encoder. Performance of proposed method is evaluated using peak signal to noise ratio (PSNR) criteria. The experimental results indicate superiority of the proposed technique in image compression.

Keywords— Artificial Neural Network, Image Compression, Improved Wavelet Shrinkage, Cuckoo Optimization Algorithm.

I. INTRODUCTION

AT the present time the data are transmitted in the form of image, graphics, audio and video. These types of data need a large storage capacity and transmission bandwidth if the data are uncompressed. Increase in the need of data transmission in Multimedia and Web applications, large amount of data are transmitted through the network. Transmission of large amount of data from one computer to another can be very time consuming. It is possible to remove some of the redundant information contained in images, bring about less storage space and less time to transmit. Therefore, the data has to be compressed by using any one of the algorithms and (image, graphics, audio and video) then it can be sent easily [1].

There are a number of image compression methods in the literature. In [2], Joint Photographic Experts Group (JPEG) has been introduced for image compression. The JPEG technique is mainly based upon the Discrete Cosine Transform. The main drawback present in this technique is some of the low bit-rates are degraded during the encoding process. In [3], the authors proposed an image compression method using wavelet thresholding and neural network. But, in this method threshold is not chosen optimally. In this article, an improved image compression method is presented. In the proposed method, the wavelet shrinkage method is initially applied on the image under analysis to remove redundant information contained in image. The threshold of wavelet

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shrinkage method is optimally set using the cuckoo optimization algorithm (COA) approach. Then, an artificial neural network is used as encoder.

This paper is organized as follows: Section 2 presents the theoretical foundation of wavelet shrinkage, cuckoo optimization algorithm and artificial neural network. The proposed image compression algorithm is explained in Sections 3. The performance evaluation of the proposed method is provided in Section 4. Section 5 summarizes our conclusions.

II. BACKGROUND KNOWLEDGE FOR THE PROPOSED METHOD

Since this research is based on wavelet shrinkage, cuckoo optimization algorithm and artificial neural network, they are briefly reviewed here.

A. Wavelet shrinkage

The Wavelet representation can be used initially to remove the noise or redundant detail of an image. The method was initially presented by Donoho [4]. In this method a discrete wavelet transform (DWT) is performed on the image first. Then with a present threshold, coefficients with magnitude smaller than the threshold are set to zero while those with larger magnitude are kept and used to estimate the noiseless coefficients. Finally, an inverse DWT (IDWT) reconstructs the image from the estimated coefficients. Choosing a threshold value play a key role in this method. In an approach [5], the threshold has been chosen as follows:

$$\sigma\sqrt{2\log M} \qquad (1)$$

Where, σ is the standard deviation of the noise and M is the length of noisy data. This threshold tending to set all the detail coefficients to zero, especially when M approaches infinite [6]. Assuming that wavelet coefficients obey the generalized Gaussian distribution (GGD), Chang et al. presented a threshold defined as below [7]:

$$T = \frac{\sigma^2}{\sigma_x} \qquad (2)$$

where σ^2 is the noise variance and σ_x is the standard deviation of noiseless coefficients in a sub band. But, this threshold may lead to undesired result due to its dependence on the number of samples.

B. Cuckoo Optimization Algorithm

Optimization is the process of adjusting the inputs to or characteristics of a device, mathematical process, or

experiment to find the minimum or maximum output or result. The input consists of variables: the process or function is known as the cost function, objective function, or fitness function; and the output is the cost or fitness [8]. An evolutionary algorithm applies the principles of evolution found in nature to the problem of finding an optimal solution to a Solver problem. There are a number of evolutionary algorithms in the literature. In a genetic algorithm [9, 10], a population of candidate solutions (called individuals, creatures, or phenotypes) to an optimization problem is evolved toward better solutions. Each candidate solution has a set of properties (its chromosomes or genotype) which can be mutated and altered; traditionally, solutions are represented in binary as strings of 0s and 1s, but other encodings are also possible . The evolution usually starts from a population of randomly generated individuals and it is an iterative process, with the population in each iteration called a generation. In each generation, the fitness of every individual in the population is evaluated. The more fit individuals are stochastically selected from the current population, and each individual's genome is modified (recombined and possibly randomly mutated) to form a new generation. The new generation of candidate solutions is then used in the next iteration of the algorithm. Commonly, the algorithm terminates when either a maximum number of generations has been produced, or a satisfactory fitness level has been reached for the population.

The basic operational principle of another evolutionary algorithm ,namely particle swarm optimization (PSO) is reminiscent of the behavior of a group of a flock of birds or school of fishes or the social behavior of a group of people [11, 12]. Each individual flies in the search space with a velocity which is dynamically adjusted according to its own flying experience and its companions' flying experience, instead of using evolutionary operators to manipulate the individuals like in other evolutionary computational algorithms.

Cuckoo optimization algorithm (COA) is a new evolutionary optimization algorithm which is inspired by lifestyle of a bird family called cuckoo [13]. Like other evolutionary algorithms, the algorithm starts with an initial population of cuckoos. These initial cuckoos have some eggs to lay in some host birds' nests. Some of these eggs which are more similar to the host bird's eggs have the opportunity to grow up and become an adult cuckoo. But, other eggs are detected by host birds and will be killed. The grown eggs show the suitability of the nests in that area. When more eggs survive in an area, the more profit attribute to that area. So the position in which more eggs survive will be the goal that COA is going to optimize. This algorithm can be summarized as follows:

1. Initialize cuckoo habitats with random points on the profit function
2. Dedicate some eggs to each cuckoo
3. Define Egg Laying Radius (ELR) for each cuckoo
4. Laying some eggs by cuckoos in their ELR
5. Host bird kill some detected eggs
6. Let eggs hatch and chicks grow

7. Evaluate the habitat of each newly grown cuckoo
8. Limit the maximum number of cuckoos
9. Cluster cuckoos and find best group
10. Migration of the cuckoos toward best group
11. Stop when stop condition is satisfied, unless go to step 2

C. Artificial Neural Networks

The commonest type of artificial neural network (ANNs) consists of three groups, or layers, of units: a layer of "input" units is connected to a layer of "hidden" units, which is connected to a layer of "output" units. The activity of the input units represents the raw information that is fed into the network. The activity of each hidden unit is determined by the activities of the input units and the weights on the connections between the input and the hidden units. The behaviour of the output units depends on the activity of the hidden units and the weights between the hidden and output units [14].

A number of different neural network models, based on learning approach have been suggested. Models can be categorized as either linear or nonlinear neural nets according to their activation function. The network will be trained by back propagation, using different learning algorithms. Mainly Newton's method, gradient descent and adaptive gradient descent learning algorithms will be used for this purpose. Artificial neural networks have been applied to many problems such as image compression [15, 16, 17]. They have the ability to preprocess input patterns to produce the simpler patterns with fewer components. This compressed information (stored in a hidden layer) preserves the full information obtained from the external environment. Not only ANN based techniques can provide sufficient compression rates, but also security is obtained. This occurs because the compressed data that is sent along a communication line is encoded and does not resemble its original form.

III. PROPOSED IMAGE COMPRESSION METHOD

In this section, a new image compression method has been introduced. In the first step, the wavelet shrinkage method is applied on the image under analysis to remove redundant information contained in image. As it mentioned before, choosing a threshold value play an important role in this method. Two parameters have been considered to calculate the threshold value. These parameters are: mean square error (MSE) which is used to evaluate the image compression quality and compression ratio (CR). MSE is defined as follows:

$$MSE = \frac{1}{M \times N} \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} \left(X(m,n) - \hat{X}(m,n) \right)^2 \qquad (3)$$

Where $M \times N$ is the size of image, $X(m,n)$, $\hat{X}(m,n)$ are the pixel gray value of the original image and compressed image, respectively. CR parameter is defined as below:

$$CR = \text{Size of Uncompressed Image/Size of Compressed Image} \qquad (4)$$

The following cost function for optimally tuning of these parameters has been suggested:

$$Cost\_Function = \alpha_1 \times MSE + \alpha_2 \times 1/CR \qquad (5)$$

Where α_1, α_2 are unitary coefficients. We minimize the cost function using COA algorithm. Then, the three-layered back propagation-learning network is used as encoder. The number of neurons in the hidden layer will be taken according to the desired compression ratio.

IV. PERFORMANCE EVALUATION

Algorithms of the proposed method were implemented using MATLAB from Math Works, Inc. The grayscale images "*lena*" is used as test image. 'sym4' wavlet has been used in wavelet shrinkage method. In the proposed method, the following COA parameters are used: number of initial population = 10, minimum number of eggs for each cuckoo = 2, maximum number of eggs for each cuckoo = 8, maximum iterations of the Cuckoo Algorithm = 100, number of clusters that we want to make = 3, Lambda variable in COA =2, maximum number of cuckoos that can live at the same time = 50, Control parameter of egg laying= 5 and population variance that cuts the optimization =1e-13. The obtained cost function after 100 iterations has been demonstrated in Figure 1. Neural network used in this experiment, have input and output layer of 16 neurons and hidden layer with 8 neurons. The original image and the compressed image are shown in Figure 2. The results of image compression using the proposed method and the two other existing approaches [3, 5] are shown in Table 1. As seen from the results, the proposed method has a better PSNR value compared to existing techniques.
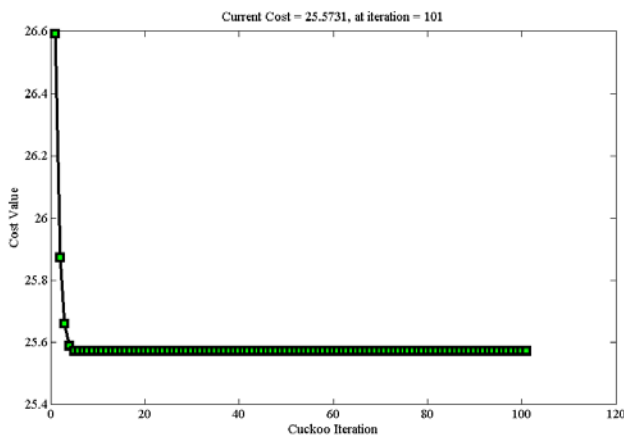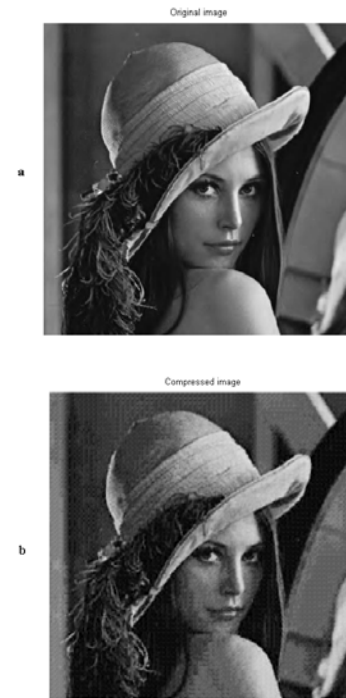

Fig 2. Image compression using proposed Method. (a) The original image, (b) The compressed image.

TABLE I
RESULTS OF IMAGE COMPRESSION USING PROPOSED METHOD AND TWO OTHER EXISTING APPROACHES.

Method	PSNR value
Proposed Method	41.88 dB
Existing method in [3]	38.20 dB
Existing method in [5]	27.11 dB

V. CONCLUSIONS

In this paper, a new image compression system based on improved wavelet shrinkage and artificial neural networks has been presented. The COA algorithm is used to choose the optimal threshold value. To facilitate the implementation of COA in image compression, a fitness function is designed in terms of MSE and CR. In order to evaluate the effectiveness of the system several experiments carried out. Simulation results indicated the efficiency of the proposed method in image compression.

Fig. 1 Cost function after 100 iterations

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