An Efficient Lossless Image Compression Based on Optimized DWT Using Genetic Algorithm

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***Abstract*—The proficient technique for compression on images is ever increasing because the raw images need large amounts of disk space seems to be a big disadvantage during transmission and storage. In this paper, an effective encryption based image compression with optimized DWT is proposed for the efficient image compression. Initially the input image is subjected to the optimized discrete wavelet transform (DWT). Here the DWT is optimized using Genetic algorithm and this optimization results into optimized approximated and detailed sub-bands. The approximated and detailed sub-bands are then encrypted using pseudo-random number sequence and RSA encryption respectively which makes the proposed scheme more secure. Furthermore, encrypted approximation sub-band is compressed by arithmetic coding while; encrypted detail sub-band is subjected to Singular value decomposition (SVD). SVD removes the noise by eliminating few singular values. Subsequently Inverse SVD will be performed so as to restore the encrypted detail coefficients. Then the restored data will be given as the input to the LZW coding for the efficient compression. After that, the compressed approximated sub band undergoes the arithmetic decoder and pseudo random number decryption while the detailed sub band undergoes the LZW decoder and RSA decryption. Finally, the decompressed image is obtained by applying inverse optimized DWT in processed approximated and detailed coefficients. The proposed work performance will be compared with the existing method to prove the better performance of our proposed work.**

Keyword: DWT, Encryption based compression, genetic optimization, LZW compression, RSA encryption, Arithmetic coding, SVD.

I. INTRODUCTION

The image is the most important carrier among the information intercommunication in people's life and the biggest media containing information. It consists of pixels that are highly correlated to each other. However, due to this correlation; it contains a large amount of redundancies that occupy massive storage space and minimizes transmission bandwidth. [1] Image compression is a technique of reducing the redundancies in image and represents it in shorter manner, which can allow more cost-effective utilization of network bandwidth and storage capacity. [2] The process of image compression has been the most researched area for decades. Image compression is a necessity for the transmission of images and the storage of images in an efficient manner. [3]

Widely image compression algorithms are classified into two major categories: (i) Lossless image compression, (ii) Lossy Compression. Lossless compression allows the reconstruction of the original image data from the compressed image data. In lossy image compression, the reconstructed image contains degradation relative to the original. In lossy compression, higher compression can be achieved when compared to lossless compression scheme. [5] In this type of image compression there is a loss of information. If the compressed image is decompressed then it will not be identical to original image but close to it. Various lossy compression techniques are listed below: Transformation coding, Vector quantization, Fractal coding and Block Truncation Coding. In lossless compression techniques, the original image can be perfectly recovered from the compressed image. Following techniques are included in lossless compression: Run length encoding, Huffman encoding, LZW coding. [6] Generally, more compression is obtained at the expense of more image degradation, i.e., the image quality declines as the compression ratio increases. Image degradation may or may not be visually apparent. [7] Lossy coding which provides great compression gains at the expense of information integrity has been widely used in digital camera, World Wide Web, mobile device and so on. On the contrary, lossless coding that holds the information integrity throughout the entire encoding and decoding process has been introduced as a necessary procedure in the application of medical images, remote sensing, satellite communications, etc. [8] JPEG (Joint Photographic Experts Group), GIF (Graphics Interchange Format), Fractal image compression and decompression and wavelet based image compression and decompression are some of the general types of image compression. [9] The most popular way to reduce storage sizes of photos is via JPEG compression. It is designed for reducing the size of photos taken in realistic scenes with smooth variations of tone and color. [10]. Fractal coding based image compression can be lossless or lossy compression; it is used for the redundancy removal from the original data after compression. [11] The image compression technique of wavelet transform uses multiscale analysis and processes the coefficients at different levels according to the degree of importance. [12]

II. Literature Survey

Ankita Vaish *et.al* [13] have proposed an wavelet based technique to compress and secure the fused images in a dependent way. The core idea behind the proposed work lied in the selection of significant and less significant information in the wavelet domain. The significant wavelet coefficients were fused using error measurements while the less significant coefficients were fused by using maximum method, the fused information of significant wavelet coefficients was compressed and encrypted using error measurement and pseudo random number sequences, while the less significant fused coefficients were compressed using a quantizing parameter, the quantized values were pseudo randomly permuted and coded using Huffman coding. At receiver side, the fused image can be recovered by using the proposed recovery algorithm. Numerical and visible results demonstrated the superiority of their technique over several other techniques..

AwwalMohammedRufai *et.al* [16] have presented a new lossy image compression technique which uses Singular Value Decomposition (SVD) and wavelet difference reduction (WDR). These two techniques were combined in order for the SVD compression to boost the performance of the WDR compression. SVD compression offers very high image quality but low compression ratios; on the other hand, WDR compression offers high compression. In the proposed technique, an input image was first compressed using SVD and then compressed again using WDR. The WDR technique is further used to obtain the required compression ratio of the overall system. The proposed image compression technique was tested on several test images and the result compared with those of WDR and JPEG2000. The quantitative and visual results were showing the superiority of the proposed compression technique over the aforementioned compression techniques. The PSNR at compression ratio of 80:1 for Goldhill was 33.37 dB for the proposed technique which was 5.68 dB and 5.65 dB higher than JPEG2000 and WDR techniques respectively.

Ming-Sheng Wu *et.al* [17] have proposed an genetic algorithm (GA) based on discrete wavelet transformation for fractal image compression. First, for each range block, two wavelet coefficients were used to find the fittest Dihedral block of the domain block. The similar match was done only with the fittest block to save seven eighths redundant MSE computations. Second, embedding the DWT into the GA, a GA based on DWT was built to fast evolutionary speed further and maintains good retrieved quality. Experiments showed that, under the same number of MSE computations, the PSNR of the proposed GA method was reduced 0.29 to 0.47 dB in comparison with the SGA method. Moreover, at the encoding time, the proposed GA method was 100 times faster than the full search method, while the penalty of retrieved image quality was relatively acceptable.

III. Proposed Flow

This section explains the proposed encryption based compression scheme. The input image is decomposed by means of optimized DWT and the resultant approximate and detailed sub bands are encrypted and then compressed. At the decompression stage, the same procedure is inversely performed to obtain the original image. Figure 1 shows the proposed block diagram.

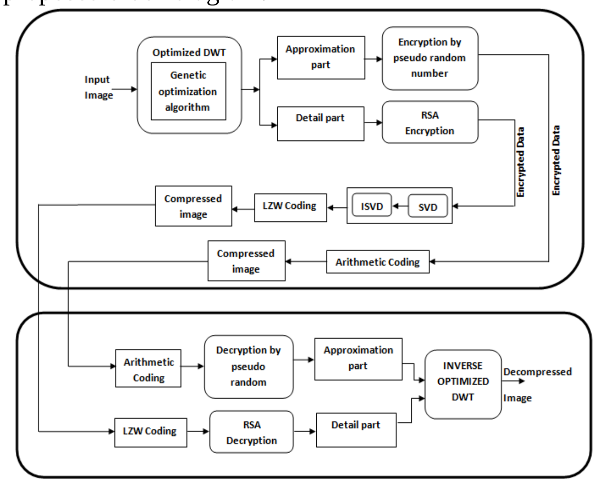


Fig. 1. Proposed block diagram

A. DWT Optimization

Consider the input image I, which is decomposed as approximation sub band (LL) and detail wavelet sub bands (LH, HL, HH) in the time-frequency domain using Optimized DWT. The DWT decomposes the input image into subbands using time domain high pass and low pass filtering technique. High pass filter gives detail coefficients or wavelet sub bands (LH, HL, HH) and low pass filter gives approximation sub band (LL). LL is the low frequency sub band containing the approximate information of the image. LH, HL and HH are the high frequency sub bands containing the detail information of the image.

The discrete wavelet can be constructed from a scaling function which describes its scaling properties. The restriction that the scaling functions must be orthogonal to its discrete translations. The wavelet which is obtained from the scaling function is given below:

$$I_d(t) = \sum_{k=-\infty}^{\infty} (-1)^k a_{N-1-k} \phi(S-k) \tag{1}$$

Where $I_d(t)$ denotes the DWT image, N represents an even integer and S represents the scaling factor. The scaling factor S is the set of wavelets, which helps to perform signal decomposition. Here krill-herd optimization is performed on the scaling factor S so as to increase the processing speed and accuracy.

B. Genetic Optimization

Genetic algorithms have been found to be capable of finding solutions for a wide variety of problems for which no acceptable algorithmic solutions exist. The GA methodology is particularly suited for *optimization*, a problem solving technique in which one or more very good solutions are searched for in a solution space consisting of a large number of possible solutions. GA reduce the search space by continually evaluating the current generation of candidate solutions, discarding the ones ranked as poor, and producing a new generation through crossbreeding and mutating those ranked as good. The ranking of candidate solutions is done using some pre-determined measure of goodness or fitness.

A genetic algorithm is a probabilistic search technique that computationally simulates the process of biological evolution. It mimics evolution in nature by repeatedly altering a population of candidate solutions until an optimal solution is found. The GA evolutionary cycle starts with a randomly selected initial population. The changes to the population occur through the processes of selection based on fitness, and alteration using crossover and mutation. The application of selection and alteration leads to a population with a higher proportion of better solutions.

The smallest unit of a genetic algorithm is called a *gene*, which represents a unit of information in the problem domain. A series of genes, known as a *chromosome*, represents one possible solution to the problem. Each gene in the chromosome represents one component of the solution pattern.

The most common form of representing a solution as a chromosome is a string of binary digits. Each bit in this string is a gene. The process of converting the solution from its original form into the bit string is known as *coding*. The specific coding scheme used is application dependent. The solution bit strings are decoded to enable their evaluation using a fitness measure.

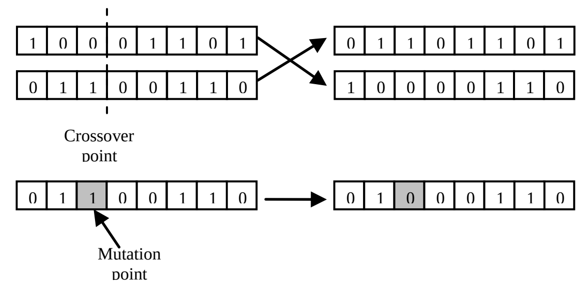
C. Selection

In biological evolution, only the fittest survive and their gene pool contributes to the creation of the next generation. Selection in GA is also based on a similar process. In a common form of selection, known as *fitness proportional selection*, each chromosome's probability of being selected as a good one is proportional to its fitness value.

D. Improve good solutions

The adjustment step in the genetic algorithm refines the good solution from the current generation to produce the next generation of candidate solutions. It is passed out by performing crossover and mutation.

- **Crossover** may be regarded as artificial mating in which chromosomes from two individuals are combined to create the chromosome for the next generation. This is done by splicing two chromosomes from two different solutions at a crossover point and swapping the spliced parts. The idea is that some genes with good characteristics from one chromosome may as a result combine with some good genes in the other chromosome to create a better solution represented by the new chromosome.



- **Mutation** is a random modification in the genetic composition. It is useful for introducing new characteristics in a population something not achieved through crossover alone. Crossover only rearranges existing characteristics to give new combinations. In the example, if the first bit in every chromosome of a generation happens to be a 1, any new chromosome created through crossover will also have 1 as the first bit.The mutation operator changes the current value of a gene to a different one. For bit string chromosome this change amounts to flipping a 0 bit to a 1 or etc. Although useful for introducing new traits in the solution pool, mutations can be counterproductive, and applied only rarely and randomly.

E. Proposed Optimized DWT-Genetic and Encryption Based Image Compression

Encryption is the most convenient strategy to guarantee the security of images over public networks. After the image decomposition, approximation sub band LL is encrypted using pseudo random numbers and the detail sub bands (LH, HL, HH) are encrypted using RSA encryption method.

An effective encryption based image constriction with optimized DWT is proposed for the efficient image constriction. Initially, the input image is subjected to the optimized discrete wavelet transform (DWT). Here the DWT is optimized using genetic algorithm and this optimization results in optimized approximated and detailed sub-bands.

The approximated and detailed sub-bands are then encrypted using pseudo-random number sequence and RSA encryption respectively which brands the suggested scheme more secure. Furthermore, encrypted appraisal sub-band is constricted by arithmetic coding while encrypted detail sub-band is subjected to Singular value decomposition (SVD). SVD removes the noise by eliminating few singular values. Subsequently, Inverse SVD will be performed so as to restore encrypted detail coefficients. Then the restored data will be given as input to the LZW coding for the efficient constriction. After that, the constricted approximated sub band undergoes the arithmetic decoder and pseudo random number decryption while the detailed sub band undergoes the LZW decoder and RSA decryption. Finally, the decompressed image is gotten by applying inverse optimized DWT in processed approximated and detailed coefficients.

IV. RESULTS AND DISCUSSIONS

Our proposed technique is implemented using MATLAB (version 14a)

On the basis of optimized Genetic algorithm the intended image compression technique is evaluated by using images obtained from the database. The performance of our proposed technique is accessed by means of performance metrics. An effective encryption based image compression is done by using Optimized DWT. Here the DWT is optimized using Proposed Genetic algorithm. At last the IDWT is performed in order to restore the original images.

Fig. 2. Input images from the database

Fig. 3. Inverse IDWT images

A. Performance Analysis

During Comparative analysis, the performance of our proposed optimized genetic algorithm is compared by means of the Conventional Optimized PSO in terms of PSNR, NSE, SSIM, Correlation, and CR performance metrics.

TABLE I. PERFORMANCE COMPARISON OF THE PROPOSED OPTIMIZED GENETIC ALGORITHM WITH EXISTING OPTIMIZED PSO IN TERMS OF (A) PSNR, SSIM, MSE (B) CORRELATION, CR

Images	Optimized GA			Optimized PSO		
	PSNR	MSE	SSIM	PSNR	MSE	SSIM
1	56.55	596.17	0.003	51.05	337.91	0.165
2	57.08	660.46	0.008	52.28	380.99	0.283
3	56.14	552.17	0.004	56.20	539.60	0.083
4	59.67	915.22	0.006	56.19	626.10	0.319
5	58.08	758.35	0.027	62.71	1264.06	0.375

(a)

Images	Optimized GA		Optimized PSO	
	Correlation	CR	Correlation	CR
1	0.3646	0.944	0.4462	0.943
2	0.4780	0.946	0.6103	0.945
3	0.5439	0.942	0.48552	0.940
4	0.3252	0.942	0.35289	0.941
5	0.4093	0.943	0.21306	0.941

(b)

B. Discussion

Table I illustrate that the performance of our optimized Genetic algorithm is equated with traditional optimization technique PSO based on the parameter like PSNR, SSIM, MSE, Correlation, CR. It reveals that our proposed shown higher values for the parameters like PSNR, SSIM, MSE, Correlation, and Compression ratio. Therefore it clearly shows that our proposed genetic optimization technique yields higher encryption based image compression results than the traditional techniques. Figure 2 illustrates the comparison graph of our proposed genetic optimization with traditional optimization PSO technique.

V. CONCLUSION

A new image compression scheme based on optimized Genetic algorithm is proposed in this research which provides sufficient high compression ratios with no appreciable degradation of image quality. The effectiveness and robustness of this approach has been justified using a set of real images from the dataset. The approximation and detail sub-bands are encrypted using pseudo random number sequence and RSA encryption respectively, which makes the proposed scheme secure. At the channel provider side, the encrypted approximation sub-band is compressed nearly losslessly which in fact helps to reduce the size of image without much more degrading the quality of reconstructed image and the encrypted detail sub-bands are compressed using SVD and LZW coding technique. Since detail sub-bands have already less information and on selection of significant information from these sub-bands indeed results good compression performance, while retaining the desirable features of the image. On receiving the encrypted and compressed image can perform the respective decompression, decryption and inverse of DWT to get the reconstructed image. The proposed Genetic Algorithm optimization has an advantage of good compression performance while retaining the desirable feature reconstructed images.

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