Image Compression and Encryption: An Overview

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Abstract

Existing methods when describe Compression there is no consideration of security, similarly when it describe encryption there is no consideration of size i.e. compression. Image Compression is concerned with minimizing the number of bit required to represent an image. Image Encryption is hiding image from unauthorized access with the help of secret key that key can be private or public. In this paper the simultaneous image compression and encryption algorithm used by different researchers are categorised and analysed with reference to the performance evaluation parameters.

1. Introduction

In the field of image processing we have to deal with huge amount of data. The general problem of image compression is to reduce the amount of data required to represent a digital image and the basis of the reduction process is the removal of spatial and psychovisual redundancies. The compression can be lossless or lossy. If the reconstructed image from the compressed image is identical to the original image then it is a lossless compression otherwise it is a lossy compression.

However alone compression is not sufficient as it has an open access, anybody can access it. So if it is desired that it can be accessible only by authorized person it should be encrypted as well. The encryption can be performed either using Symmetric key cryptography or by using Asymmetric key cryptography. If same key is used for encryption and decryption then it is called as Symmetric key cryptography and if the different key is used for encryption and decryption then it is called as Asymmetric key cryptography.

The paper contains categorisation and evaluation of simultaneous image compression and encryption schemes used by different authors. They are categorised based on the order of the two processes viz. Compression and Encryption.

The paper is organised as follows: Section 2 discusses the classification of image compression and encryption schemes. In section 3 the research work of different authors are described and categorised based on the order of the two processes viz. compression and encryption. Section 4 describes the analysis of the research work based on the performance evaluation factors. Finally in Section 5 the conclusion is discussed.

2. Classification and Description of Image Compression and Encryption Schemes

In the literature it has been seen that the image compression & encryption is carried out in any one of the following three ways:

1. *Compression followed by Encryption (CE)*

In this sequence an intruder have less cleave to access image but encryption may again increase the size.

2. *Encryption followed by Compression (EC)*

In this sequence size is not again increased but an intruder may have more clues to access the image.

3. *Joint Compression and Encryption (JCE)*

This approach is recently used which may be fast as compared to previous two but procedure is complicated.

The said categories are shown in figure 1.

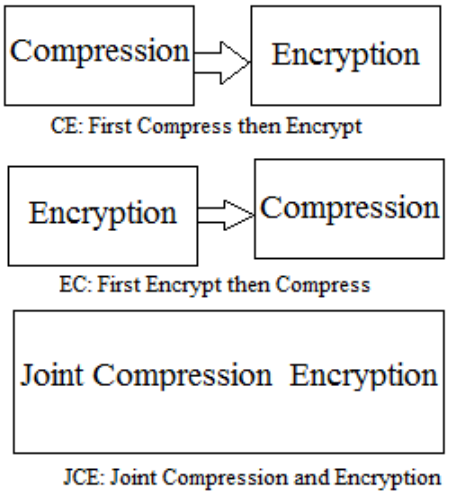

Figure 1. Classification of Compression and Encryption Scheme

3. Related Work

The research work is categorised in CE, EC and JCE categories as mentioned earlier.

3.1 CE Approach

1. Nikolaos G. Bourbakis [1] presented an image data compression-encryption scheme by using the words (patterns, or orders) produced by an image processing language called SCAN. The SCAN is a formal language-based two-dimensional spatial-accessing methodology which can efficiently specify and generate a wide range of scanning paths or space filling curves. The proposed methodology can compress and encrypt both binary and grey level images. Compression is based on Genetic Algorithm approach using fractal based language G-SCAN. Encryption is carried out using transposition cipher based on SCAN. It is based on permutation of N×N image i.e. N×N!. Compression Ratio of 2.8:1 is achieved.

2. S.S. Maniccam and N.G. Bourbakis [2] have presented a new methodology which performs both lossless compression and encryption of binary and gray-scale images. The compression and encryption schemes are based on SCAN patterns generated by the SCAN methodology. They achieved compression ratio of 1.6353 on Lena Image. The SCAN method takes about 50 seconds to compress-encrypt and about 10 seconds to decompress-decrypt a 512×512 gray scale image.

3. Howard Cheng, Xiaobo li [3] performed compression using Quadtree compression Algorithm. But partial encryption is applied. Only 13–27% of the output from quadtree compression algorithms is encrypted for typical images, and less than 2% is encrypted for 512×512 images compressed by the set partitioning in hierarchical trees (SPIHT) algorithm. Suitable for image as well as video compression but limitation is that a different scheme has to be designed and analyzed for each compression algorithm.

4. Ebru Celikel, Mehmet Emin Dalkilic [4] performed experiments on a secure compression algorithm. Results are compared using different compression techniques like Arithmetic coding, Huffman Coding, Lempel-Ziv, Prediction by Partial Matching and Burrows Wheeler. Encryption is performed using symmetric key BBS PRNG. The authors applied algorithm on text file in English and Turkish.

5. Masanori Ito *et al*. [5] proposed a method combining encryption and compression based on Independent Component Analysis (ICA) and Discrete Cosine Transform (DCT). In their method for encryption, target images are covered with an insignificant image to hide them and their mixtures to be transmitted are obtained. The receiver reconstructs the original images applying some Independent Component Analysis (ICA) algorithm to the mixed images. For compression process they used DCT and simple low pass filter. Using the proposed method the higher frequency components are cut off, that is, the quality of the original image is reduced.

6. Younggap You, Hanbyeori Kim [6] performed compression using DWT (Discrete Wavelet Transform). For encryption Standard Encryption algorithm AES or ARIA is used. Algorithm is suitable for Medical image and video. It is fault tolerant algorithm to alleviate error avalanche effect due to the erroneous bits in the received encrypted image data.

7. D. Maheswari, V. Radha [7] employed lossless compression using a novel layer based compound image compression technique that uses XML compression and JPEG to compress data. The FG layer is compressed using an XML compressor and BG layer is compressed using JPEG 2000. The encryption scheme, called, Shuffle Encryption Algorithm (SEA), proposed by Yahya and Abdalla (2008), is used. The average total time (compression time + decompression time) taken by XMLCC to compress an image was 0.79 seconds for compression and 0.68 seconds for decompression. But these results are still slower than DjVu. However the XMLCC technique is superior to both JPEG and DjVu in terms of PSNR showing an average difference of 4.6 dB and 2.13db respectively.

8. A. Alfalou C. Brosseau *et al.* [8] performed compression based on the discrete cosine transform (DCT). Two levels of encryption are used. The first one is due to the grouping of the DCTs in the spectral domain and after a second transformation, i.e. to hide the target images, one of the input images is used as encryption key. The compression is better than JPEG in terms of PSNR. The proposed method achieves PSNR as 21.7186 as compared to that of JPEG as 20.6904 on applying on Lena image.

9. Goh Han Keat *et al.* [9] observed that the conventional compression and encryption methods are too slow to carry out real time. In their research they examined Embedded Zerotree Wavelet (EZW) encoder which specially designs for wavelet compression. Stream ciphers RC4 is selected as the encryption algorithm. Three approaches have been

proposed to increase the compression efficiency and to integrate security features with minimum impact on the computation cost.
1. To Increase Security Level
2. To Reduce Space Consumption
3. Security Feature Integrate into Arithmetic Encoding.

10. N.V.Thakur and O.G.Kakde [10] proposed the compression and encryption based on the fractal coding and spiral architecture but the compression method are lossy. Additionally to reduce time complexity of fractal coding FFT based cross correlation is used. Any specific encryption method is not specified and any stream cipher algorithm can be used. Regression can be used for the encryption or even partial encryption is also possible Fractal coding is applicable for gray level however they consider the RGB color image as the combination of three gray level images. Their experimental results are better than that of quadtree method w.r.t. PSNR ratio and encoding time.

11. D.Kesavaraja *et al.* [11] observed that the conventional image compression algorithm does not run faster therefore they performed comparative study of three image compression algorithm and their variety of features and factors to choose best among them for cluster processing. For security they proposed a Distributed Intrusion Detection System to monitors all the nodes in cluster. If an intrusion is detected then a prevention step based on RIC (Robust Intrusion Control) is taken. Proposed method gives higher efficiency rate than other schemes. The Security Level is high on this Java Cluster and Intrusion Scheme. The efficiency ratio of this computation process is 91.20.

3.2 EC Approach

1. A. Kingston *et al.* [12] proposed a technique which takes advantage of the Mojette transform properties. The basic crypto-compression scheme presented is based on a cascade of Radon projection which enables fast encryption of a large amount of digital data. In their method standard encryption techniques, such as AES, DES, 3DES, or IDEA can be applied to encrypt very small percentages of high resolution images and can transmit uncorrelated data along with the encrypted part. Entropy coding is used for lossless compression. The compression ratios provided by the proposed technique cannot compete with lossless JPG2K but advantage is that the percentage of encrypted data can very strongly be reduced allowing the use of public key encryption algorithms, such as RSA.

2. Anil Kumar A, Anamitra Makur [13] suggested that compression of encrypted data is possible by using distributed source coding. They considered the encryption, followed by lossless compression of gray scale and color images. They also proposed to apply encryption on the prediction errors instead of directly applying on the images and use distributed source coding for compressing the cipher texts. Decompression and decryption are performed in a single phase. They achieved compression ratios varying from 1.5 to 2.5 despite encryption. On Lena image they obtained the compression result as 5.39 bits per pixel.

3. Fawad Ahmed *et al.* [14] used encryption scheme that relies on some very interesting properties of orthogonal matrices containing columns that form a set of orthonormal basis vectors. Compression is performed using JPEG. Image format is not an issue in this method. The proposed scheme has the capability to recover the plaintext-image from the cipher image even if the cipher-image data is compressed using JPEG lossy compression. Encryption algorithm can also be adjusted to produce cipher-image with varying perceptual distortion.

4. Mingyu Li *et al.* [15] used a RC5 stream cipher based scalable encryption scheme for low complexity transparent transcoding. CCSDS compression method is used which consist of two part DWT and Bit plane coding. Advantage is that Encryption is scalable.

5. Wei Liu *et al.* [16] used stream cipher based Slepian-Wolf coding for encryption. It is proposed to compress the image progressively, such that the decoder can observe a low-resolution. Also the compression used is lossless. Theoretical analysis shows that, despite the inefficiency of channel codes, their scheme achieves 70% to 90% rate saving of that of the optimal conventional intra-frame coder. The proposed practical system shows better coding performance than the previous approach, which exploits a 2-D Markov model in the SWC.

6. V.Radha, D.Maheswari [17] proposed image encryption algorithm that consists of two parts: scrambling of plain-image and mixing operation of scrambled image using discrete states variables of chaotic maps. Discrete Cosine transform is used for compression. The proposed algorithm is strong in providing security and is also very fast. Since the key space is large therefore the attacker cannot decrypt an encrypted image without the correct key.

3.3 JCE Approach

1. Vikram Jagannathan, *et al.* [18] proposed the method of simultaneous compression and encryption

employing Number theory paradigm. To achieve this they applied Congruence theory and Chinese Remainder Theorem. Both the lossless and lossy compression methods using Number theory are discussed. Compression ratio achieved on Lena image is 1.85 which is better than Huffman and LWZ. The proposed method has equivalent performance to JPEG2000 which achieve 1.86 compression ratio. But the performance is not better than JPEG-LS, CALIC and SPIHT. However the level of encryption offer is high.

2. A. Alfalou *et al.* [19] used DCT to jointly compress and encrypt the image with a new system able to amalgamate spectral information. That spectral fusion, nondestructive, allows the compression and the encryption of information at the same time. Authors also showed that it is possible to use the DCT to jointly realize a compression and an encryption of the data by spectral fusion thus allowing a very important gain in transmission time.

3. Shaimaa A. El-Said *et al.* [20] proposed algorithm called OMHT (Optimized Multiple Huffman Tables) technique which uses multiple Huffman tables, generated from a large set of training images that have the same type of the test image gray and colored. These images are used in a secret order (secret key). The proposed OMHT technique achieves better compression and security performance than that of MHT, and JPEG Image Compression Standard especially at low bit rate. The OMHT scheme provides high security, low encryption cost and no harm to compression ratio. Also the encryption cost of OMHT is still several times smaller than recently used COS cryptographic cipher.

4. Eric Wharton *et al.* [21] used Alpha rooting to perform simultaneous compression and encryption. This achieves improved compression performance in terms of computational complexity and compression ratio. Alpha rooting functions in the transform domain, reducing the magnitudes of the coefficients while leaving the phase unchanged. The authors achieved compression ratio of 6.0845:1on Lena Image.

5. Yunpeng Zhang *et al.* [22] Compression is carried out using JPEG2000 & uses chaotic system to encrypt the coefficient-bit and the context according to the plane coding. Since it is carried out at the same time as coding/decoding, the scheme makes the compression ratio influence small and also retains the original compression algorithm's stream elasticity, and also enjoys low cost and high security.

6. Yassin M. Y. Hasan *et al.* [23] used Vector Quantization a nonstandard asymmetric lossy image compression technique for compression. Encryption is done using Selective Encryption. It is done by applying a simple encryption algorithm to pseudo randomly shuffle the indices of the codebook before performing VQ. SE scheme selectively encrypts ~8% to ~13% of the compressed bit stream if all full indices only or both full indices and prediction tables are encrypted, respectively.

7. Li Hengjian *et al.* [24] performed Image compression using the set partitioning in hierarchical trees (SPIHT) & Encryption is based on feed forward-feedback nonlinear dynamic filter (FFNDF) to generate key and employing random arithmetic coding(RAC) for encryption. Combining the RAC with the compression methods could have advance functionalities, such as total encryption, selective encryption, and conditional access.

8. Maher Jridi, Ayman Alfalou [25] proposed a method that exploits the DCT properties to achieve the compression and the encryption simultaneously. First for compression, 8-point DCT applied to several images. Second, only some special points of DCT outputs are multiplexed. For the encryption process, a random number is generated and added to some specific DCT coefficients. An optimized DCT algorithm is proposed to reduce real time application requirements. This algorithm needs only 4 multiplications to compute relevant DCT output data. The FPGA implementation of the whole method shows improvements in terms of throughput, area and power consumption. A compression ratio higher than 65% and a PSNR about 28 dB are achieved.

9. Abraham Jun Jiang Lock *et al.* [26] performed image compression which is based on fractal image coding with little modification. Private Key cryptography using new method 'Fractal Encryption' is used. Encryption uses Mandelbrot Set. Fractal compression can provide higher compression ratio and fractal encryption can provide strong protection against the attacks.

10. Jianyong Chen *et al.* [27] proposed an approach for improving the compression performance of an existing chaos-based joint compression and encryption scheme. The lookup table used for encryption is dynamically updated in the searching process. In their modified scheme the number of chaotic map iterations wasted for visiting irrelevant symbols is reduced. The compression capability is improved, which is close to that of conventional entropy coding. Moreover, the lookup table can be

realized by memory chips or field programmable gate array FPGA, and therefore, the proposed join compression and encryption scheme is easy to be implemented by hardware circuits.

4. Analysis of various Compression and Encryption Schemes used by Researchers

Table 1. CE Approach

Author	Compression	Encryption
[1]	Fractal based language G-SCAN	Using transposition cipher based on SCAN.
[2]	by specifying a scanning path of the image using a SCAN pattern	Using transposition cipher using two keys primary and secondary
[3]	Using Quadtree compression Algorithm	Set partitioning in hierarchical trees (SPIHT) algorithm.
[4]	Arithmetic coding, Huffman coding, Lempel-Ziv, and Burrows Wheeler.	Encryption is performed using symmetric key BBS PRNG
[5]	DCT	For encryption, target images are covered with an insignificant image to hide
[6]	Using DWT(Discrete Wavelet Transform)	Using Standard Encryption algorithm AES or ARIA
[7]	Employ lossless compression using compression technique XMLCC	Shuffle Encryption Algorithm (SEA),
[8]	based on the discrete cosine transform (DCT)	By grouping of the DCTs in the spectral domain and then hiding with an input image as encryption key.
[9]	Embedded Zerotree Wavelet (EZW) encode designed for wavelet compression.	stream ciphers RC4 is selected as the encryption algorithm
[10]	Fractal coding is used. To reduce time complexity of fractal coding FFT based	Any stream cipher algorithm can be used. Regression can be used for encryption or even
[11]	Comparative study of DCT, Biorthogonal wavelets and JPEG wavelet algorithm is performed.	For security a Distributed Intrusion Detection System to monitors all the nodes in cluster.

Table 2. EC Approach

Author	Encryption	Compression
[12]	Selective Encryption using cascaded radon projection by applying standard method like AES, DES, 3DES, or IDEA is used	Entropy coding is used for lossless compression.
[13]	Encryption is applied over the bit planes of the prediction errors	Bit planes are compressed using distributed source coding based on the cross over probability.
[14]	Based on some very interesting properties of orthogonal matrices containing columns that form a set of orthonormal basis vectors.	JPEG is used
[15]	A RC5 stream cipher based scalable encryption scheme is used.	CCSDS compression method is used which consist of two part DWT and Bit plane coding.
[16]	stream cipher based Slepian-Wolf coding is used for encryption	It is proposed to compress the image progressively, such that the decoder can observe a low-resolution.
[17]	By mixing operation of scrambled image using discrete states variables of chaotic maps.	Discrete Cosine transform is used.

Table 3. JCE Approach

Author	Joint Compression & encryption
[18]	Based on Number theoretic paradigm. Chinese Remainder theorem is used to solve congruencies. Image is multiplexed in order to obtain enhanced level of security along with compression.

[19]	DCT is used to jointly compress and encrypt the image with a new system able to amalgamate spectral information.
[20]	Algorithm called OMHT (Optimized Multiple Huffman Tables) technique is proposed which uses multiple Huffman tables, generated from a large set of training images. These images are used in a secret order (secret key).
[21]	Alpha rooting is used to perform simultaneous compression and encryption. This achieves improved compression performance in terms of computational complexity and compression ratio.
[22]	Compression is carried out using JPEG2000 & uses chaotic system to encrypt the coefficient-bit and the context according to the plane coding.
[23]	Nonstandard asymmetric lossy image compression technique Vector Quantization is used for compression. Selective Encryption using a simple encryption algorithm to pseudo randomly shuffles the indices of the codebook before performing VQ.
[24]	Image compression is performed using the set partitioning in hierarchical trees (SPIHT). Encryption is based on feed forward-feedback nonlinear dynamic filter (FFNDF) to generate key and employing random arithmetic coding for encryption.
[25]	Used DCT properties to achieve the compression and the encryption simultaneously. Only some special points of DCT outputs are multiplexed. For the encryption process, a random number is generated and added to some specific DCT coefficients.
[26]	Compression is based on fractal image coding with little modification. Private key cryptography using new method 'Fractal Encryption' is used. Encryption uses Mandelbrot Set.
[27]	An approach for improving the compression performance of an existing chaos-based joint compression and encryption scheme is proposed. The lookup table used for encryption is dynamically updated in the searching process.

5. Conclusion and Future Scope

In this paper, many of the current important image compression and encryption techniques have been presented and analyzed. The best way of fast and secure transmission is by using compression and encryption of multimedia data like images.

The research works have been categorized in the following three categories based on the order of the two process viz. CE, EC or JCE.

The compression technique observed is either lossy or lossless. Always lossless compression is preferred but to achieve secrecy some image quality degradation is accepted.

Encryption applied by different researchers by means of encrypting algorithm which encrypt the entire or partial multimedia bit sequence using a fast conventional cryptosystem .

The performance evaluation factors are PSNR ratio and coding decoding time for compression and encryption respectively. But the balancing parameter for the combined process is not yet been defined.

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