SPATIAL IMAGE COMPRESSION USING FUZZY TRANSFORM AND EDGE DETECTION

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Abstract- *In this paper, lightweight lossy compression algorithm, F-transform is presented which is effectively helpful in reducing data transmission and reception of images in WSNs. Such applications as networks of environmental sensors, where signals tend to be smooth and have low fluctuations, can benefit from compression using the FTC technique. The F-transform puts a continuous/discrete function into a correspondence with a finite set of its F-transform components. In image processing, where images are identified with intensity functions of two arguments, the F-transform of the latter is given by a matrix of components. We recall the definition of the F-transform and give it for a function of two variables defined on the set of pixels P with intensity ranging [0,255]. It has been recall that the inverse F-transform approximates the original function with an arbitrary precision and by this, can be chosen as an appropriate technique for reconstruction of the compressed data. Also different compression rates has been applied based on gradient edge detection method in which low, mid and high edge blocks have been determined based on which different compression ratios has been used. To encrypt data, Huffman coding is applied in order to increase security of the data. Experimental results shows that proposed method is efficient for compression and decompression of data and gives acceptable image quality after decompression when measured with PSNR, SSIM, MSE quality metrics*

Keywords- Image compression, data encryption, Gradient, edge detection etc.

I. INTRODUCTION

Most of the application including remote sensing, medical etc., requires high quality image for analysis and interpretation. Especially medical diagnosis and analysis is generally based on magnetic resonance imaging, X-Ray, computer tomography, ultrasound imaging etc. The raw image data obtained from such techniques occupy several megabytes of disk space. These images should be stored in any health care center for at least two decades and in some cases it is transmitted to the physician for future medical diagnosis or legal purposes. To speed up the electronic transmission and to minimize the computer storage space, generally medical images are compressed into smaller files. During compression and decompression, the medical images must maintain all original details at the time of reconstruction. Hence there is a challenging task to deal the transmission and storage of medical images with high diagnostic quality.

There are several techniques used to compress the image and are generally categorized as:

- lossy and
- lossless compression.

High compression ratio can be obtained using lossy compression with a compromise in terms of quality where as in lossless compression high quality is possible with low compression ratio. Commonly used lossy compression technique is fractal image compression (FIC). Fractal encoding is based on every object contains similar information and repeating patterns which are called fractals. Fractal algorithm converts the image into mathematical data based on repeating pattern into fractal code. This fractal code is used to decode image. Alossy compression using FIC technique is implemented for medical Images [1]. The result shows that the Fractal encoding scheme exhibits longer encoding time. Medical Images like CT and MRI Images are compressed with FIC using quad-tree Partitioning technique to enhance the compression performance.

Compression scheme using quadtree decomposition in FIC with Huffman encoding is implemented for satellite images [2]. In FIC original gray level of the image is subdivides into non overlapping blocks based on threshold value using quadtree decomposition. Decomposition can be per-formed with threshold value of 0.2; finally Huffman coding is used to encode the image. The main disadvantages of FIC is longer encoding time, lot of research has been done to reduce the encoding time in FIC. The FIC encoding time is reduced by Adaptive Fractal Image compression (AFIC) [3]. In AFIC encoding time is reduced by minimizing the matching operation during decomposition. The domain block and range block can be reduced during the matching process. Quadtree partitioning with zero mean level FIC is used for compression. Lossless compression is particularly used in the application which requires the source image and reconstructed images are identical, generally preferred for application such as medical industry, remote sensing, satellite imagery etc.

Various lossless encoding techniques are available to compress the image such as: Huffman coding,

- Arithmetic coding,
- Run length coding etc.

In these techniques, compression is obtained by reducing the redundancy of image pixels. While reducing the redundancy, it is very difficult to maintain the quality. In most of the compression, images are transformed into another domain to increase the redundancy and then encoding is performed. This method is called transformed based compression. Various transform like DCT, DWT etc can be used for transforming the image from spatial to frequency domain. Wavelet transform with different wavelet basis can be used to perform the transform of test image. the image can be compressed, accessed and sent over telemedicine network [4].

II. LITERATURE SURVEY

F. Kamisli et al. [5] performed Conventional intra-frame coding by copying based spatial prediction of a block of pixels and then applying the conventional 2D DCT on the prediction residual block.

R. Ravi et al. [6] presented the fast efficient SPIHT algorithm that operates through SPIHT and accomplishes completely with VLSI domain coding. The realization of the principle matched coding and decoding algorithm is new one and is shown to be more effective than in precious implementation of SPIHT code compression.

Mohammed M. Siddeq et al. [7] presented and demonstrated a new method for image compression and illustrated the quality of compression through 2D and 3D reconstruction, 2D and 3D RMSE. Their compression algorithm is based on DCT applied to each row of an image, then followed by DST which is applied to each column of the matrix.

Qingtang Su et al. [8] proposed a blind watermarking based on DC coefficients in the spatial domain. When embedding watermark, the principle of DC coefficient modification in DCT domain is used to repeatedly embed watermark in the spatial domain for four times, which can improve the invisibility and the robustness of watermark.

Pingzhang Zhou et al. [9] show that the number of design variables in density-based topology optimization can be phenomenally reduced using discrete cosine transform (DCT), which is one of the most frequently used transforms in digital image compression.

B. Vidhya et al. [10] proposed a new image compression method based on two dimensional discrete wavelet transform along with the examplar based in-painting. This approach mainly aimed in preserving the textural features of the image by categorizing the image regions into texturally important and non-important regions.

Sobia Amin et al. [11] analyze various techniques of fractal encoding for compressing the image. After doing the analysis, we have found the advantages and limitations of many techniques. It has been found that the decay has been reduced to a greater extend by existing technique, and encryption process has been improved.

III. STEPS IN THE ALGORITHM

The proposed image compression method follows three steps in which edge detection is performed first. Then F-transform based fuzzy compression is applied based on the density of the edges found in 8*8 blocks of the image. In the end, Huffman coding is used to encrypt the data matrix. Similar steps are applied in reversible to decompress the image. The brief of all three sections has been provided as below

Edge detection using derivative of center pixel with respect to 3*3 neighbor pixels

In this step, each input image block is classified into either a low intensity (LI), a medium intensity (MI) or a high intensity (HI) block using derivative based detection algorithm. The algorithm starts by dividing the image into overlapping blocks that would be individually evaluated for inclusion of edges.

N1	N2	N3
N4	Current Pixel location	N5
N6	N7	N8

Figure 1: (a) 3 × 3 Neighborhood pixels

Below are the detailed implementation steps.

Step a) Divide the image C into overlapping blocks of the size n × n.

Step b) Compute the absolute mean difference between the left and right columns of the block (magnitude of vertical edge). Repeat same for horizontal, first diagonal and second diagonal edges.

Step c) Find the maximum of the four values and assign it to e. If e > Th, then the block is considered to be an edge block, otherwise it is not an edge block. Construct E that contains the calculated e value of each of the edge blocks, and 0 for non-edge blocks. A binary edge image can also be constructed, which contains 1 for edge blocks and 0 for non-edge blocks. The edge images indicate the ability of this method in detecting edges with an acceptable accuracy.

Step d) Compression using Discrete F-transform

In this Section, we introduce the F-transform of an image u that is considered as a function $u:[0,N]\times[0,N]\to[0,1]$ where $N=255$. It is assumed that the image is gray-scaled and that it is defined at points (pixels) that belong to the set $P=\{(i,j)|i,j-0,1,...,N\}$.

Let $A_1,...,A_n$ and $B_1,...,B_m$ be basic functions, $A_1,...,A_n:[0,N]\to[0,1]$ and $B_1,...,B_m:[0,N]\to[0,1]$ be two fuzzy partitions of $[0,N]$ (not necessarily different). Assume that the set of pixels P is sufficiently dense with respect to the chosen partitions. This means that $(\forall k)(\exists i\in[0,N])A_k(i)>0$ and $(\forall l)(\exists j\in[0,N])B_l(j)>0$.

We say that the $n\times m$-matrix of real numbers $[U_{kl}]$ is called the (discrete) F-transform of u with respect to $\{A_1,...,A_n\}$ and $\{B_1,...,B_m\}$ if for all $k=1,...,n,\ l=1,...,m,$

$$U_{kl}=\frac{\sum_{j=1}^{M}\sum_{i=1}^{N} f(p_i,q_i)A_k(p_i)B_l(q_j)}{\sum_{j=1}^{M}\sum_{i=1}^{N} A_k(p_i)B_l(q_j)}......(1)$$

The elements U_{kl} are called components of the F-transform.

The inverse F-transform $\hat{u}:P\to[0,1]$ of the function u with respect to $\{A_1,...A_n\}$ and $\{B_1,...B_m\}$ is defined as follows:

$$\hat{u}(i,j)=\sum_{k=1}^{n}\sum_{l=1}^{m}U_{kl}A_k(i)B_l(j)........(2)$$

The function $\hat{u}$ approximates the original function u on the whole domain $P=\{(i,j)|i,j=0,1,...,N\}$ with a given precision. Moreover, the following estimate was established in [13] for every continuous function u on a domain P and its inverse F-transform $\hat{u}$ that is computed with respect to h-uniform fuzzy partitions $\{A_1,...,A_n\}$ and $\{B_1,...,B_m\}$ of $[0,N]$:

$$\max_{t\in P}|\hat{u}(t)-u(t)|\le\mathbb{C}\omega(h,u)........(3)$$

where C is a constant $t=(i,j)$ and $\omega(h,u)$ is the modulus of continuity of u on P^2.

Step e) Encryption of data to increase security

For encrypting the F-transform data , Huffman coding is applied .Huffman algorithm is a popular encoding method used in electronics communication systems. It is widely used in all the mainstream compression formats that you might encounter—from GZIP, PKZIP (winzip, etc) and BZIP2, to image formats such as JPEG and PNG. Some programs use just the Huffman coding method, while others use it as one step in a multistep compression process. Huffman coding & deciding algorithm is used in compressing data with variable-length codes [12]. The shortest codes are assigned to the most frequent characters and the longest codes are assigned to infrequent characters. Huffman coding is an entropy encoding algorithm used for lossless data compression. Entropy is a measure of the unpredictability of an information stream. Maximum entropy occurs when a stream of data has totally unpredictable bits. A perfectly consistent stream of bits (all zeroes or all ones) is totally predictable (has no entropy).

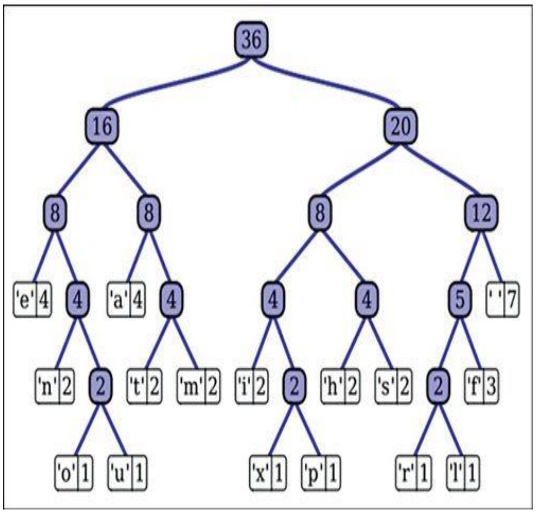

Figure 2: Huffman tree

The Huffman coding method is somewhat similar to the Shannon–Fano method. The main difference between the two methods is that Shannon–Fano constructs its codes from top to bottom (and the bits of each codeword are constructed from left to right), while Huffman constructs a code tree from the bottom up and the bits of each codeword are constructed from right to left. The model for Huffman tree is shown here in the figure. It is generated from the sentence “this is an example of a huffman tree” using Huffman algorithm. Here 36 is the root of the tree. Below the root node you can see the leaf nodes 16 and 20. Adding 16 and 20 gives 36. Adding 8 and 8 gives 16, while 4+4=8. On the left-hand side, ‘e’ is attached to 4. Similarly, ‘a’, ‘n’, ‘t’, etc. have been attached to form the complete Huffman tree. The simplest tree construction algorithm uses a priority queue or table where the node with the lowest probability or frequency is given the highest priority. First, create a leaf node for each symbol or character and add it to the priority table. If there is more than one node in the table, remove two nodes of the highest priority (lowest frequency) from the table. Create a new node with these two nodes as sub-nodes and with probability equal to the sum of the two nodes’ probabilities. Continue in this way until you reach the last single node. The last node is the root, so the tree is now complete.

IV. RESULTS AND DISCUSSIONS

PERFORMANCE EFFICIENCY

A. Structural Similarity Index Measurement

$$SSIM(x,y)=\frac{(2\mu_x\mu_y+C_1)(2\sigma_{xy}+C_2)}{(\mu_x^2+\mu_y^2+C_1)(\sigma_x^2+\sigma_y^2+C_2)}$$

….. (4)

Where C1 and C2 are constant and equal to unity

When both images are same, SSIM is 1 so a Value nearer to 1 would normally indicate high reconstruction quality.

B. PSNR and SAD

PSNR is given from

$$PSNR=10\log_{10}\left[\frac{R^2}{MSE}\right]$$

(5)

For sake of completeness, we also evaluate PSNR and SSIM along with Sum of Absolute Differences (SAD) defined as

$$\sum_{i=1}^{N}\sum_{j=1}^{M}|R(i,j)-D(i,j)|$$

(6)

Table 1: Different quality metrics for Koala and Barbara image

Parameters	PSNR		SAD		SSIM	
Image used	Existed Method	Proposed method	Existed Method	Proposed method	Existed Method	Proposed method
	25.89	29.021	288128	200030	0.7730	0.87388
	24.49	28.41	324022	203349	0.7668	0.8837
	25.06	27.61	337618	246511	0.7224	0.8338
	27.41	31.17	196136	130888	0.8740	0.9264

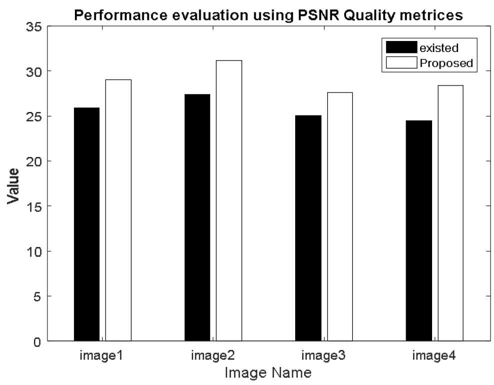

Figure 3: Performance evaluation using PSNR Quality metrics

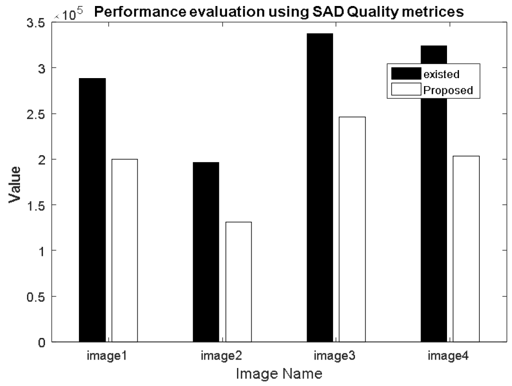

Figure 4: Performance evaluation using SAD Quality metrics

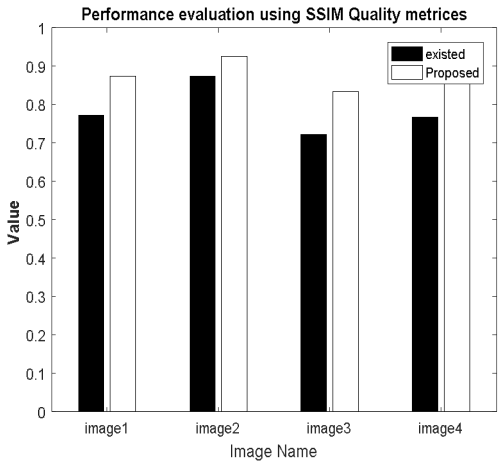

Figure 5: Performance evaluation using SSIM Quality metrics

It has been concluded that proposed method using derivative based edge detection gives better results when compared with canny edge based edge detection method.

V. CONCLUSION

Many image compression techniques have been developed to suit different applications. Broadly speaking, image compression techniques can be classified into lossless and lossy. Lossless compression techniques allow for a perfect reconstruction but can only achieve low compression factors. Lossy image compression techniques can provide high compression ratios but produce some compression errors. However, by taking advantages of the physiology of human visual system and the redundant nature of images, images compressed by lossy techniques can be reconstructed with acceptable image quality. In this work, We propose algorithm to compress and decompress image data with the help of a fuzzy technique, namely the F-transform. Three steps have been proposed in which first step gives edge detected image based on horizontal, vertical and diagonal gradients. The second step uses fuzzy transform by dividing image into same size non-overlapped square blocks to compress them by different compression rates based on number of edges in a block. Third step used for data encryption in order to secure data on transmission channel in which Huffman coding is used. Same process is applied in reversible in which first encrypted data is decrypted by Huffman decoding, and then inverse fuzzy transform is applied to get the decompressed image. The quality of reconstructed image was qualified by various measures i.e. MSE, PSNR, RMSE, SSIM etc.

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