Research Article

Fractal Image Compression Based on High Entropy Values Technique

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Abstract

There are many attempts tried to improve the encoding stage of FIC because it consumed time. These attempts worked by reducing size of the search pool for pair range-domain matching but most of them led to get a bad quality, or a lower compression ratio of reconstructed image. This paper aims to present a method to improve performance of the full search algorithm by combining FIC (lossy compression) and another lossless technique (in this case entropy coding is used). The entropy technique will reduce size of the domain pool (i. e., number of domain blocks) based on the entropy value of each range block and domain block and then comparing the results of full search algorithm and proposed algorithm based on entropy technique to see each of which give best results (such as reduced the encoding time with acceptable values in both compression quality parameters which are C. R (Compression Ratio) and PSNR (Image Quality). The experimental results of the proposed algorithm proven that using the proposed entropy technique reduces the encoding time while keeping compression rates and reconstruction image quality good as soon as possible.

Keywords: Fractal Image Compression, Entropy, Image Quality, Domain Pool, Similarity, Encoding.

الخلاصة

هناك عدة محاولات أجريت لتحسين وقت الترميز في خوارزمية ضغط الصور الكسورية بسبب انها مستهلكة للوقت. هناك محاولات عدة تم عملها لتقليل حجم مستودع البحث لكل عملية مطابقة بين المدى و المجال لكن اغلب هذه المحاولات أدت الى كفاءة رديئة او نسبة ضغط قليلة للصورة المسترجعة. هذا البحث يهدف الى تقديم طريقة لتحسين أداء خوارزمية البحث الكلي من خلال دمج و تركيب خوارزمية البحث الكلي التقليدية التي هي من نوع Lossy Compression Algorithm مع خوارزمية الانتروبي المقترحة التي هي من نوع Losseless Compression Algorithm. تقنية الانتروبي المقترحة تقلل من حجم مستودع المجال Domain Pool (عدد بلوكات المجال) و بالتالي تقلل عدد المقارنات بين بلوكات المدى و المجال بالاعتماد على قيمة الانتروبي لكل من بلوكات المدى و المجال و من ثم حساب نتائج الخوارزمية البحث الكلي التقليدية و مقارنتها مع نتائج تقنية المقترحة لرؤية أي خوارزمية تعطي نتائج افضل (تقلل من وقت البحث المستغرق مع تحقيق نسب مقبولة في كفاءة الصورة المسترجعة PSNR و نسبة الضغط). النتائج التجريبية للخوارزمية المقترحة اثبتت ان استخدام تقنية الانتروبي المقترحة يقلل من وقت الترميز و يحافظ على نسبة الضغط و كفاءة الصورة المسترجعة على قدر الإمكان.

Introduction

The goal of image compression is to reduce the amount of data required to represent a digital image [1]. Fractal compression is a lossy compression method for digital images, based on fractals [2]. The idea of fractal image compression (FIC) also named full search algorithm was originally introduced by Barnsley in 1988 and the first practical FIC scheme was realized by Jacquin in 1992 [3] since each natural image has sub sections and the pixels of each subsection have great self-similarity to each other that is called Partitioned Iterated Function System or PIFS [4]. FIC is best suited for textures and natural images, relying on the fact that parts of an image often resemble other parts of the same image [2] which can be regarded as possessing fractal nature [5]. In full search algorithm, fixed block size partitioning will be used to generate the range and domain blocks. The main drawback of FIC is larger computational time in encoding stage because 8- symmetry mappings that must be tried to each domain block and then select the symmetry case of the domain block that led to least square error (lesser difference) and optimum matching when comparing this domain block with range block this caused that the number of comparisons between range and domain block is $\mathbf{8n_r n_d}$. Number of the range blocks can be calculated using $(\mathbf{N/n})^{\mathbf{2}}$ while number of the domain blocks can be calculated using $(\mathbf{N}-\mathbf{2n}+\mathbf{1})^{\mathbf{2}}$ where $\mathbf{N}$ is image dimension while $\mathbf{n}$ is block dimension.

In order to reduce the computation time, different optimization techniques have been proposed. The main objective of this paper is to develop an efficient optimization technique for FIC which is called "entropy technique" that involves performing the search in part of domain pool rather than over the whole domain pool by reducing the domain pool size based on entropy value of both range and domain blocks this make the domain pool more productive. Using proposed FIC based on entropy technique has two fundamental targets which are speeding up the encoding time by check the entropy value of all domain blocks in the domain pool, the domain blocks having high value of entropy threshold (ε) will be excluding while the domain blocks having low value of ε only will be selected. This technique will reduce size of the domain pool, therefore the matching stage pair of range and domain blocks will be achieved in faster time. Also the other target is keeping on quality of the reconstructed image good after their construction as well as increasing compression ratio. The balance of the paper is organized as follows: introduction to fundamentals of FIC scheme is given in section 1. The proposed encoding and decoding stages of the proposed algorithm based on entropy technique are described in sections 2 and 3. The experimental results of our proposed entropy technique and comparing this technique with full search algorithm are illustrated in sections 4-A and 4-B. Finally, some concluding remarks are given in section 5.

1. The Encoding Stage in Proposed FIC Based on Entropy Technique

As said before that full search algorithm is time consuming so that a new approach must be proposed to overcome this problem. In this paper, entropy technique will be used; it is information theory that provides the basic tools needed to deal with image representation directly and quantitatively. The proposed FIC based on entropy technique is similar to the full search algorithm expect few differences. See Figure 1 that explains the main steps of the proposed FIC based on entropy technique. The proposed entropy technique can be illustrated in the following points:

a. Generating Range and Domain Pools

Generating range and domain pools starting with loading the original image into its buffer to create the range image and generating the domain image from the range image by down sampling process using averaging method then the range and domain blocks must be formed to need them in the remaining steps in the encoding stage by partitioning the range and domain images using quad tree technique since the range blocks are non-overlapped to make the decoder capable of reconstruction the image while the domain blocks are allowed to be overlapped depend on the step size values where allowing the domain blocks to be overlapped improving quality of the reconstructed image. In proposed FIC we will use quad tree partitioning technique to generate these range and domain blocks since the reasons that make us use this partitioning technique is by using quad tree technique more acceptable quality of reconstructed images will be obtained as well as because each range block will be compared only with four domain blocks so the encoding time for FIC systems that use this technique will be less than these FIC systems that use fixed block size partitioning technique which this most important reason. Mean absolute error (MAE) which can be calculated using equation 1 is used to decide whether range and domain blocks partitioned or not since MAE of range and domain blocks are computed then comparing MAE of range block with MAE of domain block must be occurred if MAE difference of them within specific threshold then range and domain blocks are not partitioned (they are similar):

$$MAE = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}(| x(i,j) - y(i,j) |)...(1) \quad (1)$$

Otherwise this means that these blocks are not similar then partitioning of these blocks will be applied. The specific threshold that used to decide whether MAE values of range and domain blocks are approximate or non is minimum block error (MBE) which its tested values in our work are (0.1, 0.01, 0.001, 0.0001 and 0.00001). If the difference between MAE values of range and domain blocks lesser than MBE then these blocks are partitioned otherwise no partitioning process is implemented. The matching computation will be reduced in the proposed algorithm where the entropy values of the range and domain pools will be computed and used these values to find the best matching between pairs range-domain locks in an encoding stage.

b. Entropy Values Determination

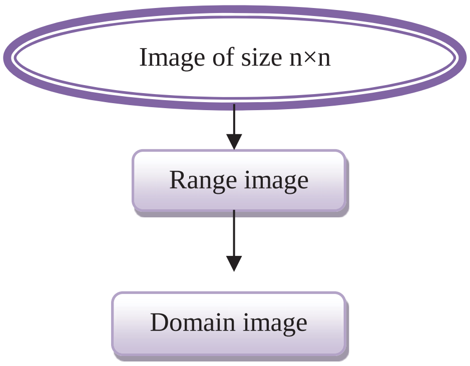
After completing the partitioning process, the domain pool size is resulted very large, this size will be consume time in the encoding stage when searching in the domain pool to find the best matched domain block that satisfied least error for each pair range-domain blocks. In the best matched domain block that satisfied least error for each pair range-domain blocks. In the proposed algorithm, the entropy values will be computed from equation 2 to each range and domain blocks separately. In the encoding stage, the best matching between the entropy values of range with the entropy values of domain block can be found if these blocks satisfied the condition in equation 3:

$$entropy = -\sum_{i=1}^{n} p_i \log p_i \ldots(2)$$

$$\left|\mathbf{entropy}(\mathbf{R_i}) - \mathbf{entropy}(\tilde{\mathbf{D}}_\mathbf{j})\right| \leq \boldsymbol{\varepsilon} \ldots (\mathbf{3})$$

Where: p is the probability value, $\tilde{\mathbf{D}}_\mathbf{j}$ is the average of domain block, and ε is the entropy threshold. Before searching and matching processes, the entropy values of range and domain blocks must be tested to show whether the domain block satisfy this condition or not.

In this paper entropy threshold (ε) determined to be in values from 0.1 to 0.9 where according to ε a decision will be made to determine if the domain block belong to the domain pool or not.



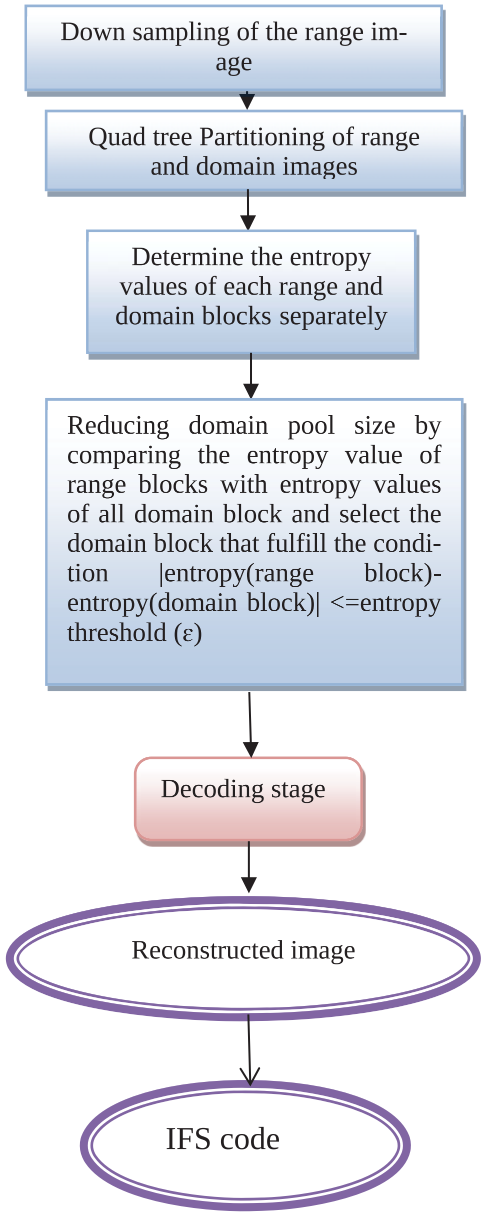


Figure1: The schematic diagram of proposed FIC based on entropy technique.

According to equation 3 the new reduced domain pool will be formed since if the difference of entropy values between range and domain blocks lesser than or equal to ε then this domain block will join to the domain pool. Otherwise the domain block will be discarded and excluded from the domain pool so the new domain pool consists of only the domain blocks that have low entropy value instead of all domain blocks this will lead to reducing number of the comparisons for finding the best matched domain block for each range block and then speeding up the encoding time. Ɛ value will be controlled parameter in the encoding stage, if ε value is high this mean that the encoding stage need long time to be done (large domain pool). But if ε value is small the encoding process need short time to compare the domain block in domain pool with suitable range block (small domain pool). This process will reduce the encoding time with acceptable quality of the reconstructed image.

c. Searching and Matching Processes

After computing the entropy values of all range and domain blocks, the searching and matching process among each range block and all overlapped domain blocks in the reduced domain pool size must be done but may be noticed that range and domain blocks must be at the same size since must not comparing range and domain blocks of different sizes.

In general, the best matched domain block must be found for each range block so that the error between each range block and all domain block will be computed based on their entropy values but before calculating the error the scale coefficient s_i must be calculated and quantized as well as index of the quantized scale coefficient must be computed. If the computed error lesser than minimum block error (MBE) then this domain block will consider the best matched block and information of the best matched domain block such as the position (x_d , y_d) and index of quantized scale I_s will be stored in the compressed file (Frac) but the quantized offset coefficient doesn't be saved in the compressed file because the offset coefficient doesn't change the entropy value of the block. After that the searching process will continued for another range block.

Otherwise, if the computed error greater than minimum block error (MBE) then newly searching process in the reduced domain pool for the range block will be done until finding the best matched domain block with minimum error. The proposed encoding stage diagram can be shown in Figure 2. In this work, index of quantized scale coefficient will be stored in IFS code instead of quantized values of it to reduce the size of compressed file (to increase the compression ratio C. R) and to access to the quantized scale coefficient. Also, to increase the compression ratio, the values of x_d and y_d must be minimized.

At the end, result of the encoding stage is compressed file (code book file or IFS code) where the compressed files of both full search and proposed algorithms contain the similar information expect compressed file of the proposed algorithms doesn't contain index of the quantized offset I_o. The compression information must be saved in header of the compressed IFS file before starting the encoding stage such image width (W), image high (H), block length, step size, no. of bit used to quantize scale coefficient, maximum and minimum scale coefficient, entropy threshold ε and MBE to make the decoder capable of reconstruction the original image from the compressed file. The decoder needs this information to reconstruct the original image.

2. The Decoding Stage

The decoding stage in proposed FIC based on entropy is similar to the decoding stage in full search algorithm since this process very fast when compared with encoding stage which considers the first advantage of decoding stage because no searching step for finding the best matched domain block for each range block which spent a lot of time. Any initial image can be taken such as zero images and then reconstructed the compressed image from it. To reconstruct the compressed image, the range image must be created by loading the initial image into a buffer and then domain image must be created by down sampling range image.

The same as to the decoding stage in full search algorithm, range and domain images must be partitioned using quad tree partitioning that used in encoding stage. Before starting the decoding stage, content of the header in IFS code must be extracted because they are necessary to integrate other parameters that the decoder need them also the quantized values of scale coefficient (s_q) must be de-quantized to their original values since we can arrive to these quantized scale coefficient by using quantized scale indexes as well as coordinate of the best matched domain block (x, y) also must be reconstructed to their original value. Now, all data of IFS code become prepared to be using them in reconstruction operation since content of each domain block multiplied by de-quantized scale value to reconstruct the range blocks, these steps will continue until small or no change appear in quality of the reconstructed image.compression ratio (C. R), PSNR, bit rate (B. R) and mean square error (MSE) are calculated using the following equation to need them in section 4:

$$compression - ratio(CR) = \frac{Original - image - size}{Compressed - image - size} \ldots(4)$$

$$PSNR(db) = 10\log_{10}\frac{(L-1)^2}{MSE} \ldots(5)$$

$$MSE = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}(x(i,j) - y(i,j))^2 \ldots(6)$$

$$Bit\ Rate = \frac{number\ of\ bits}{number\ of\ pixels} = \frac{(8)\ number\ of\ bytes}{N\times N} = \frac{8\times N\times N}{N\times N} \ldots (7)$$

Where : L is number of the grey levels in the image M, N is image dimensions, x(i, j) is the original image, y(i,j) is the reconstructed image, N is high or width of an image.

Experimental Results

Experimental results were implemented using Visual Basic (Ver.6.0). It is tested on laptop Acer, 2 GHz processor. Entropy technique had been tested specially on bitmap grey scale images of size n × n since in this thesis we will use lenna, golden hill, girl, train and plane images of size (256 x 256 pixel, 8-bits) as a test images as well as other color images of size (256 x 256 pixel, 24-bits) are also used in experimental tests.

Results of the Decoding (Reconstruction) Stage Based on Entropy Technique

The sample images are compressed using MBE, block length ,step size, scale bits ,maximum scale and entropy threshold (ε) parameters since these parameters are set to be (0.0001, 4, 2, 11, 0.9, 0.8) respectively, Figure 3 can be shown to observe results of applying the proposed algorithm on these sample images. Newly, the encoding parameters will be set again to be (0.001, 8, 2, 12, 0.8, and 0.7) respectively to show the new effects on these sample images in Figure 4. Because in the proposed entropy technique, the offset coefficient doesn't be used in compression process since as said in section 2 the offset coefficient don't change the entropy value of the block so the memory of offset coefficient will be exploited to enlarge the number of bits that used to store scale coefficient to arrive to the 12-bit this give chance for obtaining on best results of the reconstructed images using proposed technique.

Comparing Results of Full search algorithm and Proposed FIC Based on Entropy Technique

To verifying from any proposed algorithm give the required results the comparing between this proposed algorithm and traditional algorithm must be done so that results of the proposed algorithm that use quad tree partitioning will be compared with results of full search algorithm that use fixed block partitioning and sure from does that proposed algorithm speed the encoding time and reconstruct the images with acceptable C. R and PSNR or not, see Tables 1, 2 and 3. See Figures 5, 6 and 7 that show the reconstructed images in both full search algorithm and proposed algorithm according to the encoding parameter values which determined in Tables 1, 2 and 3.

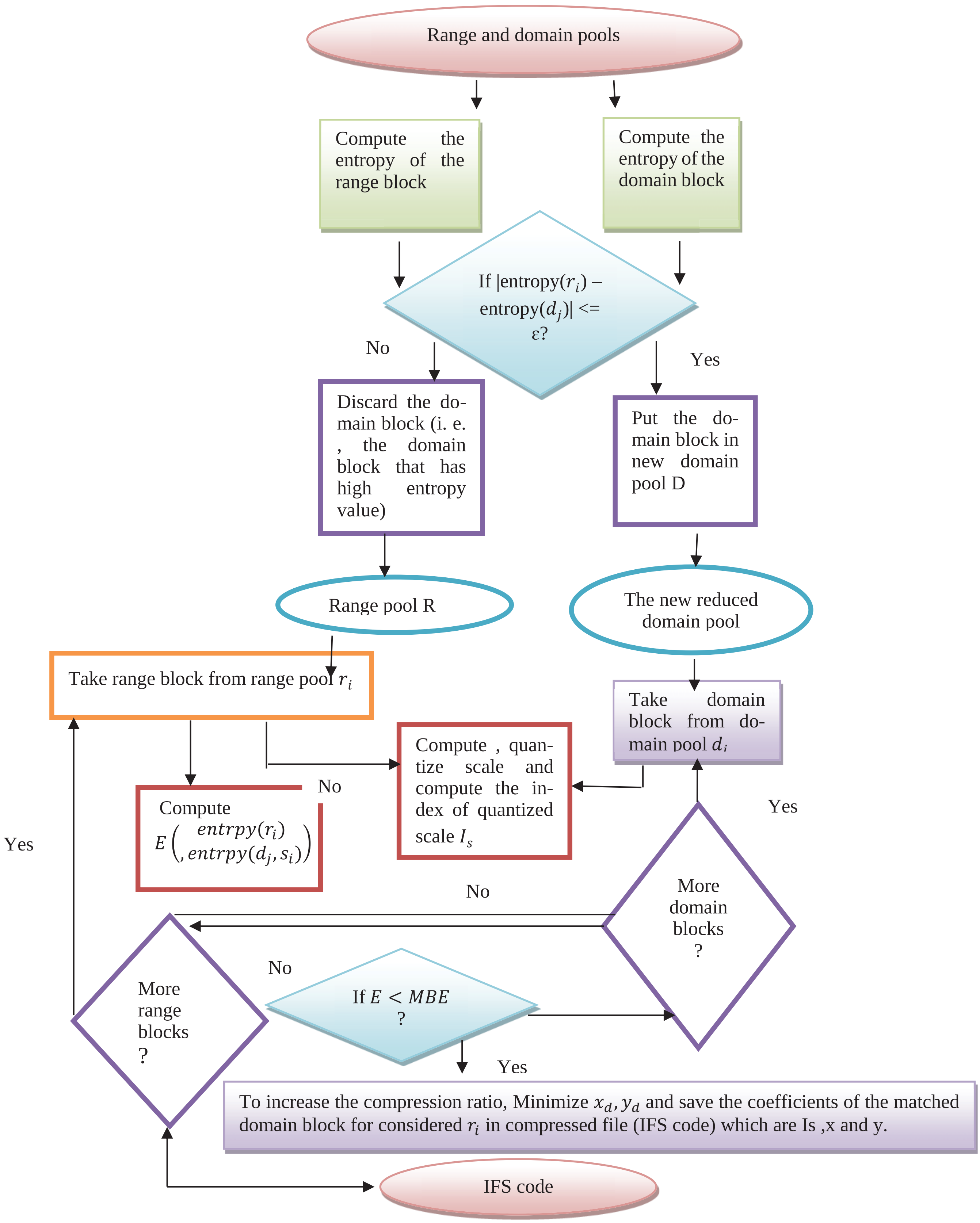


Figure 2: The proposed encoding stage diagram.

Original Image:
Lenna Image (24-bit)

The Reconstructed Image
E. T=120.230 sec
C. R=52.63
PSNR=21.230 dB
MSE=489.76
MAE=38.390
B. R=16.313 bpp

Original Image:
Lenna Image (8-bit)

The Reconstructed Image
E. T=109.51 sec
C. R=69.066
PSNR=27.155 dB
MSE=125.17
MAE=8.241
B. R=12.510 bpp

Original Image:
Rose Image

The Reconstructed Image
E. T=124.74 sec
C. R=46.241
PSNR=27.254 dB
MSE=122.35
MAE=16.675
B. R=12.975 bpp

Figure 3: Reconstructed images with its values

The Reconstructed Image
E. T=79.56 sec
C. R=177.604
PSNR=19.959 dB
MSE=656.33
MAE=35.235
B. R= 3.378 bpp

The Reconstructed Image
E. T=80.36 sec
C. R=168.099
PSNR=18.282 dB
MSE=965.74
MAE=46.436
B. R= 3.569 bpp

Original Image:
Fruits Image

The Reconstructed Image
E. T=120.95 sec
C. R=35.366
PSNR=19.586 dB
MSE=715.17
MAE=43.920
B. R=10.858 bpp

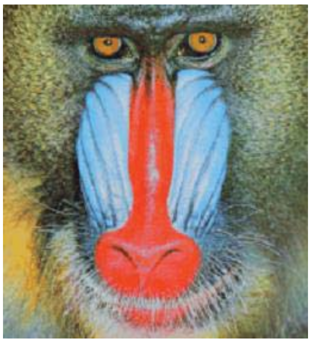
Original Image:
Golden Hill Image

The Reconstructed Image
E. T=109.14 sec
C. R=23.583
PSNR=22.863 dB
MSE=336.32
MAE=24.784
B. R=4.071 bpp

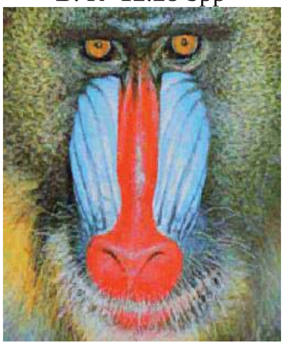
Figure 3: Reconstructed images with its values

Original Image:
Girl Image

<u>The Reconstructed Image</u>
E. T=109.18 sec
C. R=70.323
PSNR=22.070 dB
MSE=403.69
MAE=40.547
B. R=12.28 bpp



Original Image:
Mandrill Image



<u>The Reconstructed Image</u>
E. T=123.26 sec
C. R=53.633
PSNR=24.363 dB
MSE=238.10
MAE=16.219
B. R=15.110 bpp

Figure 4(a): Reconstructed images with its values

Original Image:
Train Image

<u>The Reconstructed Image</u>
E. T=112.20 sec
C. R=56.393
PSNR=14.258 dB
MSE=2124.5
MAE=80.430
B. R=10.640 bpp

Original Image:
Lake Image

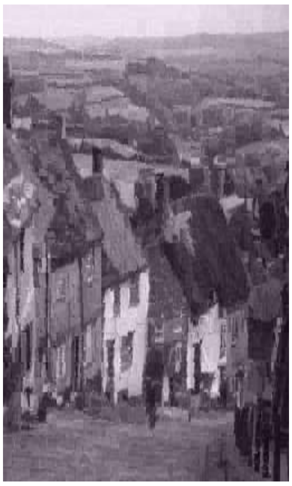
<u>The Reconstructed Image</u>
E. T=121.45 sec
C. R=18.552
PSNR=29.270 dB
MSE=76.919
MAE=6.319
B. R=5.174 bpp

<u>The Reconstructed Image</u>
E. T=79.80 sec
C. R=169.023
PSNR=25.640 dB
MSE=177.44
MAE=9.016
B. R=3.550 bpp

<u>The Reconstructed Image</u>
E. T=70.81 sec
C. R=177.284
PSNR=17.787 dB
MSE=1082.3
MAE=51.341
B. R=2.166 bpp

Figure 4 (b): Reconstructed images with its values

The Reconstructed Image
E. T=79.08 sec
C. R=171.53
PSNR=20.132 dB
MSE=630.71
MAE=32.438
B. R= 3.508 bpp



The Reconstructed Image
E. T=74.02 sec
C. R=45.343
PSNR=18.551 dB
MSE=907.66
MAE=44.684
B. R=0.529 bpp

The Reconstructed Image
E. T=80.36 sec
C. R=168.099
PSNR=18.282 dB
MSE=965.74
MAE=46.436
B. R=3.569 bpp

The Reconstructed Image
E. T=79.67 sec
C. R=140.084
PSNR=30.807 dB
MSE=53.991
MAE=5.157
B. R=2.741 bpp

Newly, the encoding parameters will be set again to be (0.001, 8, 2, 12, 0.8, 0.7) respectively to show the new effects on these sample images in Figure 4 (a and b).
Because in the proposed entropy technique, the offset coefficient doesn't be used in compression process since as said in section 2 the offset coefficient don't change the entropy value of the block so the memory of offset coefficient will be exploited to enlarge the number of bits that used to store scale coefficient to arrive to the 12-bit this give chance for obtaining on best results of the reconstructed images using proposed technique.

Comparing Results of Full search algorithm and Proposed FIC Based on Entropy Technique

To verifying from any proposed algorithm give the required results the comparing between this proposed algorithm and traditional algorithm must be done so that results of the proposed algorithm that use quad tree partitioning will be compared with results of full search algorithm that use fixed block partitioning and sure from does that proposed algorithm speed the encoding time and reconstruct the images with acceptable C. R and PSNR or not, see Tables 1, 2 and 3. See Figures 5, 6 and 7 that show the reconstructed images in both full search algorithm and proposed algorithm according to the encoding parameter values which determined in Tables 1, 2 and 3.
Finally, the main important reasons that make the proposed encoding stage faster than the encoding stage in full search algorithm will be explained in the following points:
1-Using quad tree partitioning technique which reducing the encoding time of proposed FIC technique since every range block will compared with only 4- domain block in every search process of finding best matched pair of range – domain blocks while in the full search algorithm fixed block partitioning is used which slowing the encoding time since every range block will compared with all domain blocks in every comparing time.
2-Reducing size of the domain pool according to the entropy threshold (ε) participate in decreasing size of the searching space that led to reducing the number of comparing for finding the best matched domain block for each range block.

Table 1: Comparing results of full search and proposed algorithms

The encoding parameters of both algorithms are block length=4, MBE=0.00001, step size=2, scale bits=7, offset bits=10 (only for full search algorithm), MaxScale =1, ε=0.6

Experimental Results of Full search algorithm

Image Name	**E. T**	**C. R**	**PSNR**	**MSE**	**MAE**	**B. R**
Lenna (24-bit)	821.16	8.476	33.873	26.651	3.222	2.831
Lenna (8-bit)	803.26	11.088	31.320	147.970	9.184	2.164
Fruits	834.68	8.387	31.094	50.538	4.234	2.861
Golden Hill	796.41	11.291	36.747	13.751	1.418	2.126
Mandrill	901.70	8.534	30.622	56.352	5.302	2.812
Girl	788.07	11.192	40.898	5.287	1.288	2.144
Rose	436.83	8.957	42.917	3.321	1.757	2.680
Train	732.58	10.956	25.230	195.01	8.924	2.191
Lake	233.28	8.073	33.413	29.631	3.350	2.675
Plane	805.64	11.637	36.031	16.215	1.909	2.062

Experimental Results of Proposed FIC Based on entropy technique

Image Name	**E. T**	**C. R**	**PSNR**	**MSE**	**MAE**	**B. R**
Lenna (24-bit)	121.11	25.429	26.396	149.11	16.912	8.494
Lenna (8-bit)	105.41	11.088	24.611	224.89	17.937	2.164
Fruits	120.65	41.937	25.931	165.94	13.232	14.307
Golden Hill	107.03	11.291	24.449	233.43	22.593	2.126
Mandrill	120.11	34.132	25.453	185.25	16.674	11.249
Girl	110.29	33.576	35.451	18.531	4.172	6.433
Rose	121.54	53.426	35.826	16.997	5.653	16.172
Train	111.59	32.867	24.503	230.54	9.644	6.572
Lake	123.46	8.973	29.851	67.293	2.095	2.675
Plane	106.56	58.185	29.144	79.182	8.345	10.312

The reconstructed images using full search algorithm

The reconstructed images using proposed algorithm

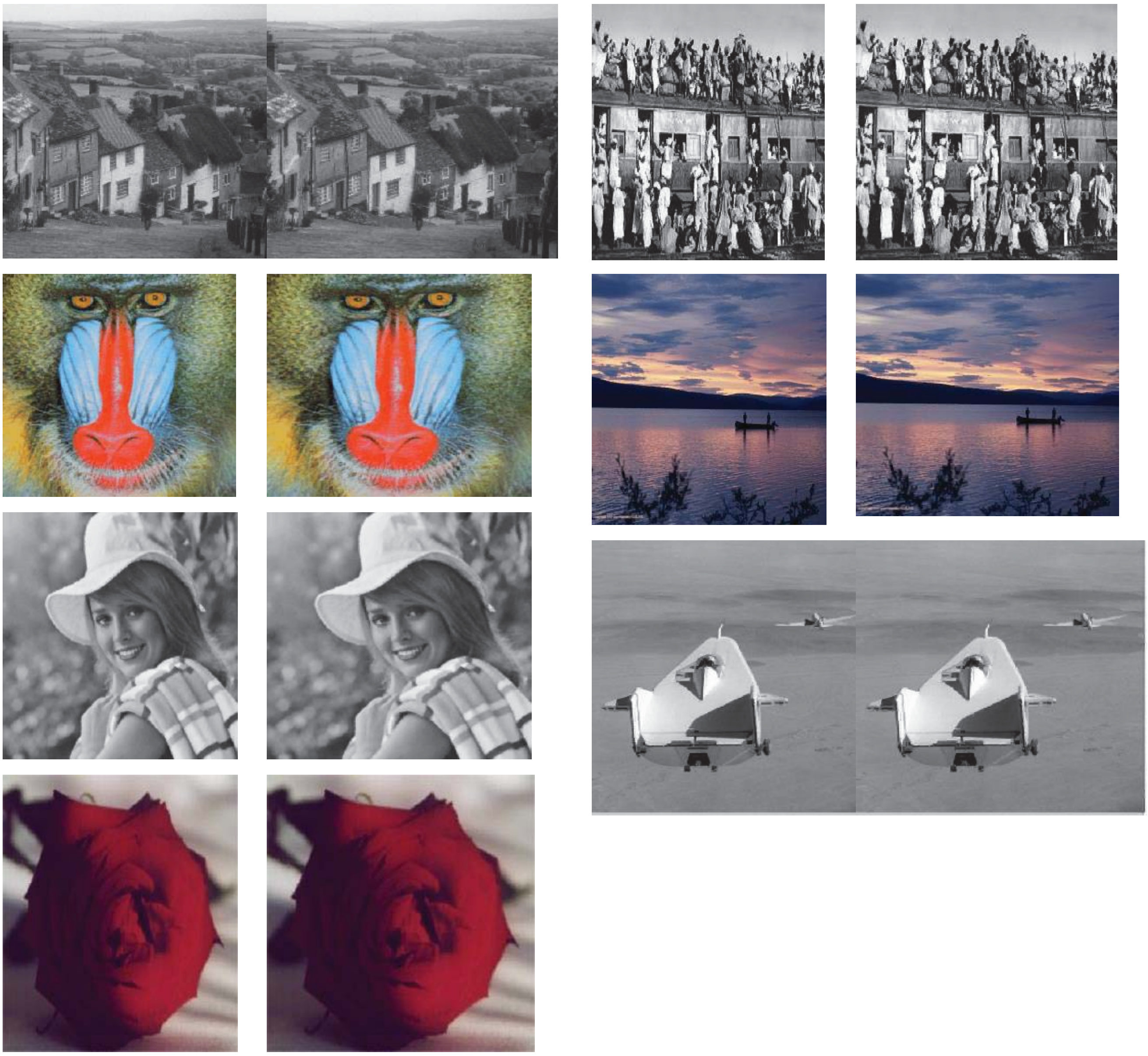


Figure 5: Comparing in reconstructed images between full search algorithm and proposed algorithm based on entropy technique (using parameter values in Table 1).

Table 2: Comparison results between full search and proposed algorithms

The encoding parameters of both algorithms are block length=4, MBE=0.00001, step size=2, scale bits=9, offset bits=6 (only for full search algoritm), MaxScale =0.8, ε=0.7

Experimental Results of Full search algorithm

Image Name	E. T	C. R	PSNR	MSE	MAE	B. R
Lenna (24-bit)	903.94	9.151	32.758	34.457	3.953	2.623
Lenna (8-bit)	802.67	11.849	29.860	67.140	5.455	2.026
Fruits	899.85	9.120	30.363	59.799	4.920	2.632

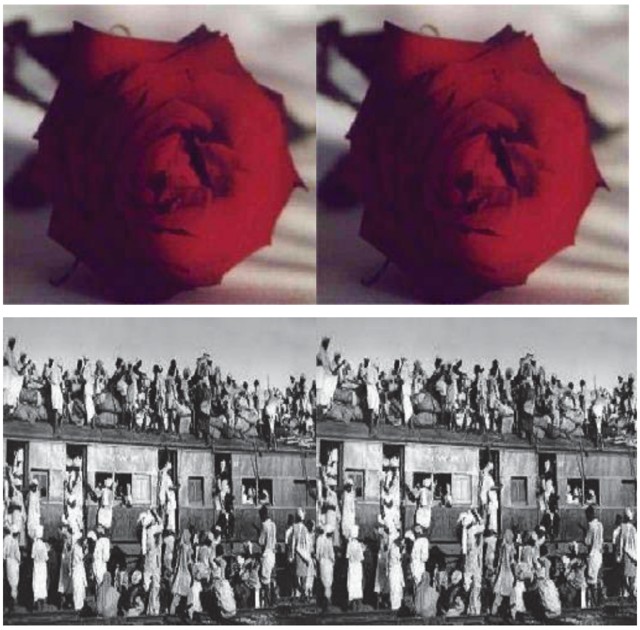
Golden Hill	796.91	11.291	36.747	13.751	1.418	2.126
Mandrill	913.49	9.255	30.005	64.937	5.783	2.593
Girl	789.49	12.057	35.748	17.306	3.388	1.990
Rose	722.172	9.640	38.611	8.952	2.249	2.490
Train	806.14	11.619	24.120	251.83	10.568	2.066
Lake	881.05	9.674	32.326	38.054	4.094	2.481
Plane	785.52	12.619	32.977	32.765	3.894	1.918

Experimental Results of Proposed FIC Based on Entropy Technique

Image Name	E. T	C. R	PSNR	MSE	MAE	B. R
Lenna (24-bit)	119.34	45.757	25.402	187.41	15.482	13.113
Lenna (8-bit)	109.50	35.547	22.040	406.425	33.302	6.071
Fruits	124.63	45.600	24.223	245.88	19.944	13.158
Golden Hill	114.41	60.695	22.687	350.20	33.173	9.886
Mandrill	120.69	18.510	26.784	136.32	11.901	5.187
Girl	110.16	72.344	35.659	17.666	3.416	11.943
Rose	115.91	38.560	30.690	55.972	13.740	9.958
Train	109.39	46.477	19.523	725.60	31.307	8.262
Lake	121.80	9.674	32.117	39.931	4.216	14.886
Plane	108.88	62.578	25.835	169.64	17.276	9.588

The reconstructed images using full search algorithm

The reconstructed images using proposed algorithm



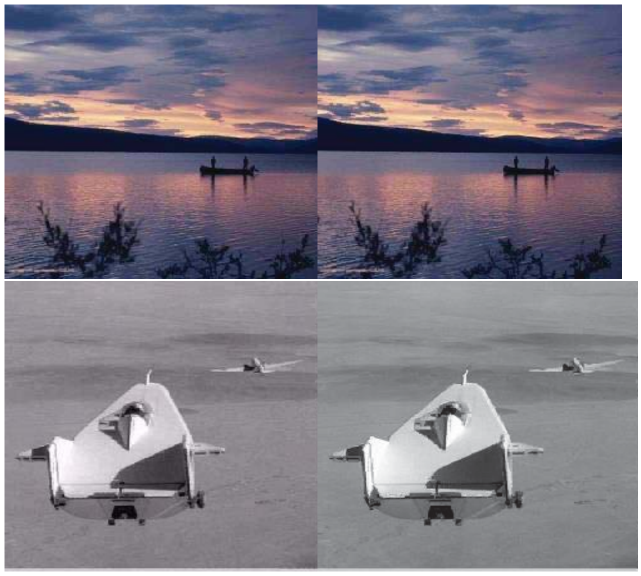


Figure 6: Comparison in reconstructed images between full search algorithm and proposed algorithm using based on entropy technique (using parameter values in Table 2).

Table 3: Comparison results between full search and proposed algorithms.

The encoding parameters of both algorithms are block Length=4, MBE=0.001, step size=3, scale bits=10, offset bits=10 (only for full search algoritm), MaxScale =0.9, ε=0.9

Experimental Results of Full search algorithm						
Image Name	**E. T**	**C. R**	**PSNR**	**MSE**	**MAE**	**B. R**
Lenna (24-bit)	324.53	7.950	33.269	30.630	3.441	3.019
Lenna (8-bit)	362.28	10.483	30.482	58.191	4.520	2.894
Fruits	403.75	7.872	30.623	56.326	4.480	3.049
Golden Hill	377.602	10.664	36.048	16.151	1.536	2.251
Mandrill	416.15	8	30.140	62.960	5.623	2.999
Girl	279.52	10.575	39.931	6.605	1.480	2.269
Rose	102.85	8.610	41.655	4.441	1.391	2.787
Train	308.44	10.364	24.322	240.32	9.879	2.316
Lake	341.77	8.404	32.743	34.572	3.619	2.856
Plane	393.93	10.972	34.821	21.428	2.169	2.187
Experimental Results of Proposed FIC Based on entropy technique						
Image Name	**E. T**	**C. R**	**PSNR**	**MSE**	**MAE**	**B. R**
Lenna (24-bit)	54.48	31.799	27.332	120.174	11.592	12.076
Lenna (8-bit)	47.45	31.449	29.799	68.168	4.927	6.868
Fruits	54.55	7.872	30.346	60.04	4.602	3.049
Golden Hill	48.14	53.319	26.155	157.59	14.487	11.253
Mandrill	54.82	8	22.782	342.63	29.341	2.100

Girl	47.73	10.575	31.586	45.127	4.140	2.269
Rose	53.26	49.951	42.166	3.949	1.202	17.297
Train	49.16	41.457	17.851	1066.5	41.579	9.263
Lake	55.32	8.385	29.272	76.886	7.535	2.862
Plane	48.02	43.888	29.399	74.662	6.928	8.750

The reconstructed images using full search algorithm

The reconstructed images using proposed algorithm

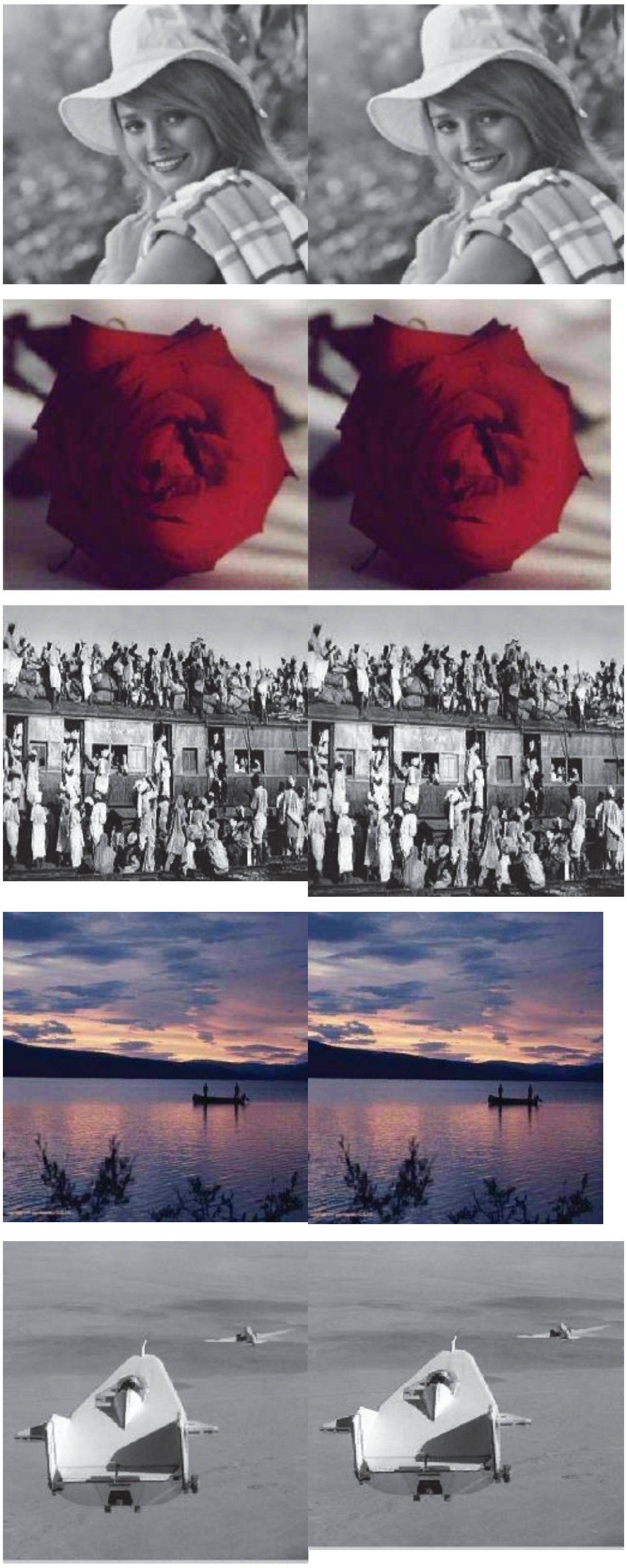


Figure 7: Comparison in reconstructed images between full search algorithm and proposed algorithm based on entropy technique (using parameter values in Table 3).

Conclusions

The experimental results in Tables 1, 2 and 3 which include 10 grey scale and color images of size 256 × 256 indicate that the proposed FIC algorithm based on entropy technique reconstructed the images with faster E. T and acceptable C. R as well as good quality of the reconstructed image.

The resulted C. R by proposed algorithm within the values that ranged from 7.872 to 72.344 which consider acceptable values when compared with C. R values of full search algorithm that ranged from 7.950 to 12.619 this means that the proposed algorithm reconstruct the images with C. R values better than C. R values of full search algorithm also the proposed algorithm reconstruct the images with good PSNR values which ranged from 17.851 dB to 42.166 dB that close to PSNR values of full search algorithm which included in values from 24.120 dB to 42.917 dB.

Relatively E. T, must be noticed from the mentioned tables that the highest E. T value of full search algorithm (for step size is 2 of Mandrill image) was 913.49 sec while the highest E. T value of the proposed algorithm (for the same step size of Mandrill image) was 120.69 sec this means that E. T of full search algorithm decreased about 792.8 sec where the main target from the proposed algorithm is breaking the slowing encoding time problem after then the secondary targets is to reconstruct the images with acceptable C. R and good PSNR that also invoked by the proposed algorithm as shown from results of the previous Tables.

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