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DCT Image Compression by Run-Length and Shift Coding Techniques.

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ABSTRACT

The mathematical concept of a DCT transform is a powerful tool in many areas; it is also, served as an approach in image processing discipline. In this work an image is processed as three color channel. The correlated pixels values of an image can be transformed to a representation where its coefficients are de-correlated. The term "de-correlated" means that the transformed values are independent of one another. As a result, they can be encoded independently, which make it simpler to construct a statistical model. Correlated values are coded with run-length coding techniques while shift coding used to decode the DC term and the other five lifting values. In this work, we suggest to save the first five values from every block to keep it back without any significant errors. The obtained bit rates was extended to be within range (11.4 , 2.6), compression ratio (2.76 , 13.34)the values of the fiedility parameters (PSNR) was within the range (31.61 , 46.21) for the lena test image in both sizes (128×128 and 256×256), and PSNR was calculated as average for the three color channels, red, green , blue.

Introduction

Many evolving multimedia applications beside the advent of World Wide Web applications require high quality visual information to be stored and transmitted over the network, despite rapid progress in mass storage density, processor speeds and digital system demands for data storage capacity and transmission bandwidth to outstrip the capacity of available technology [1].

Image compression fall into two categories according to weather the compressed file preserves very detail perfectly or allow some errors in data, lossless and lossy image compression, this also depend on the reconstructed file, some files does not accept any type of errors like text compression, images are less affected by errors depending on the quality were needed [6][7].

Image compression measurements

Image compression means that reduce the amount of bits required to represent an image, this also depend on the quality retrieved by compressed image which changes according to loss of information in acceptable levels.

Beside the reducing of image file size, image compressor must retain necessary information which is represented in the field of low level information.

Obviously, we need a way to measure compression defined in Compression Ratio CR, BitRate, BR, and fidelity criteria to expose the reconstructed image MSE, PSNR as below[2]:-

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$$CR = \frac{Original\ image}{Compressed\ image} \quad \ldots\ldots\ldots\ldots(1)$$

$$BR = \frac{\text{Compressed image}}{Original\ image} \quad \ldots\ldots\ldots\ldots\ldots(2)$$

$$MSE = \frac{1}{n}\sum_{i,j}(x(i,j)-y(i,j))^2 \quad \ldots.\ (3)$$

where

x(i,j) = value of original pixel.

y(i,j) = value of reconstructed image pixel.

n = number of pixels.

$$PSNR = 20\log_{10}\left[\frac{MSE}{\max x(i,j)}\right] \quad \mathbf{.\ (4)}$$

Image compression techniques

Common most characteristics of most images is the redundant information of adjacent pixels which have been correlated, Compression try to make these adjacent redundant values de-correlated , Compression system had to contain three basic procedures to accomplish image compression, first we must choose an appropriate transform, second quantize transform to reduce redundant information here, the quantized data contains errors, third encode the quantized values, encoding change the format of values to variable length according to type of coding techniques[3]. These techniques are:-

- Run Length Encoding (RLE)

RLE is lossless compression that represent any group of data as (item, run), this coding is useful when we find long stream of redundant items, if there is no variable changes RLE may enlarge file size[4].

- Shift Coding

Shift code is generated by implementing the following steps:

a. Arrange the source symbols so that their probabilities are monotonically decreasing.
b. Dividing the total number of symbols into symbol blocks of equal size.
c. Coiling the individual elements within all blocks identically.
d. Adding special shift-up and/or shift-down symbols to identify each block.

The individual symbols are then coded by using the fixed length binary coding method (i.e, using 000 through 110). The code (111) is used as a single shift-up control that identifies the remaining blocks (in such method a shift-down symbol is not necessary). The symbols in the remaining two blocks are then coded by one or two shift-up symbols in combination with the binary code used to code the reference block [17]. For example, a source symbol 19 is coded as 111 111 110

Discrete Cosine Transform (DCT)

The major key to the Joint Photographic Experts Group (JPEG) compression is the mathematical transformation known as Discrete Cosine Transform (DCT). Its basic operation is to take a signal and transforms it from one type of representation to another, in this case the signal is a block of an image, and the concept of this transformation is to transform a set of points from the spatial domain into an identical representation in frequency domain. It identifies pieces of information that can be effectively thrown away without seriously reducing the image's quality[3].

The mathematical function for two-dimensional DCT is:

$$D(i,j)=\frac{1}{\sqrt{2n}}c(i)c(j)\sum_{x=0}^{n-1}\sum_{y=0}^{n-1}p(x,y)\cos\left[\frac{(2x+1)i\pi}{2n}\right]\cos\left[\frac{(2y+1)j\pi}{2n}\right] \quad \text{....(5)}$$

where

$$c(u)=\begin{cases}\frac{1}{\sqrt{2}} & \text{if } u=0\\ 1 & \text{otherwise}\end{cases} \quad \text{.. (6)}$$

p(x,y) is the (x, y)th element of image.

n is the size of block that the DCT is applied on.

The Proposed Compression Technique

First of all, DCT breaks the source image into (N×N) blocks down, in practice (N) is most often taken (8), because a larger block (though would probably give better result) often takes a great deal of time to perform DCT calculations, figure (1) show compression stages in more details.

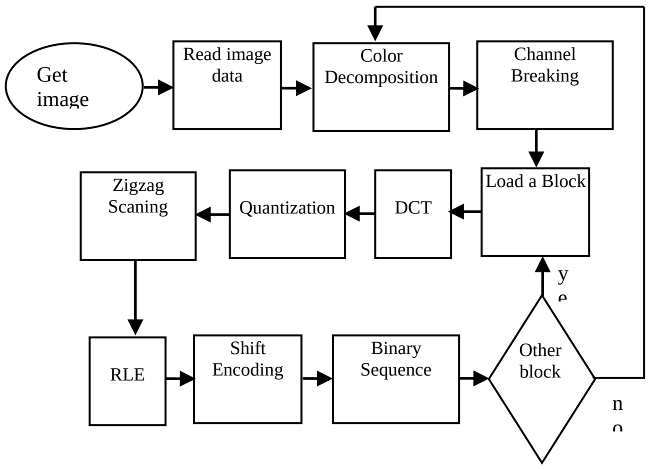
Our suggested compression system uses image blocks with size (8×8) pixels. Therefore, N is taken 8, and (x,y) range from (0 to 7), therefore D(i,j) would be rewritten as follows:-

$$D(i,j)=\frac{1}{4}c(i)c(j)\sum_{x=0}^{7}\sum_{y=0}^{7}p(x,y)\cos\left[\frac{(2x+1)i\pi}{16}\right]\cos\left[\frac{(2y+1)j\pi}{16}\right] \quad \text{.....(7)}$$

Compression Algorithm

Input: Image, quality factor (QF): output: stream of binary bits.

1- Get an image.
   - Break it to three channel (red, green, blue)
   - Distribute every channel to blocks (8×8) pixels,
2- Calculate DCT for every block.
3- By using (QF) Quantize every channel.
4- Rearrange every block to one dimensional array, this rearrange process called *zigzag* scanning.
5- Leave the first five DC coefficients for every block then apply RLE, lifting here has great influential to keep the Image in good quality.
6- Shift coding for every block to get stream of bits in a binary file.



Figure(1) stages of compression.

- **Getting Image:** images should be BMP format.
- Decompose channels :At this stage, the color values of each pixel are extracted and separated into three color channels (red, green and blue).
- Breaking every channel to 8×8 blocks**.**

All of the following steps are executed to every color channel separately:-

- **Apply DCT:** As a first step the color channel data (red, green and blue) of the image is picked up, follow that the partitioning of the channel data into 8×8 blocks, as DCT requires that. DCT can work on 4×4, and 16×16 blocks too, these two block sizes may cause time consuming and/or degradation of image quality when applied, we choose the size 8×8 blocks, so the quality is the better, also the compression ratio would be good.

The DCT decomposes these 64 discrete values into 64 uncorrelated coefficients. The value at location (0,0) is called the DC coefficient, representing the most low (zero) frequency value, usually it is the largest value in the output.

- Quantization

Quantization most effective stage on the image data, there is a low frequency data and a high frequency data, quantization emphasize the low frequency data, and try to converge the high frequency data to zero, as the zero had not to save or in other words it does not require memory, lifting scheme discipline is that DC coefficients has the most low frequency value that is most affected by human eyes[5], where the location (7,7) is the highest frequency value which represent the edges,

The applied equation of quantization process is the following:

$$q(i,j) = 1 + \alpha \times (i + j) \qquad \ldots(9)$$

where

c(i,j) is the DCT coefficients.

$c_q(i,j)$ is the corresponding quantization index.

q(i,j) is the corresponding quantization step , it is determined by using the following expression:

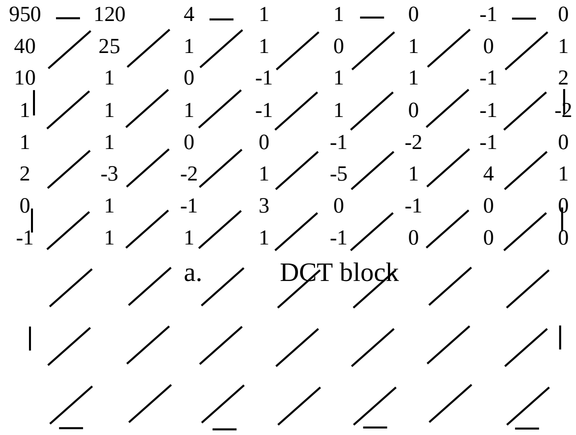
$$c_q(i,j) = round\left[\frac{c(i,j)}{q(i,j)}\right] \qquad \ldots(10)$$

where

(α) is the quality factor.

Figure (2.a) presents the DCT coefficients after quantization stage.

- Scanning block to one dimensional array
  - by scanning (visiting) the coefficients from top left to the bottom right in zigzag way, Zigzag scan process rearrange the coefficients of each quantized block, This will produce one dimensional block (vector), at the first element of every block is the DC coefficient, followed by the remaining lifting coefficients. Because so many coefficients in the quantized image are truncated to zero values, these zero values are handled differently form non-zero values[8]. Zigzag will produce long runs of zeros, figures (2.a) and (2.b) explain the zigzag scan.



a. DCT block

950	120	40	10	25	4	1	1	1	1	1	1	0	1	….etc
DC coeff.	1st lifting	2nd	3rd	4th										

b. One dimensional array after zig-zag scan.

Figure (2) Zig-zag scan

- RLE Coding

In this search we use run length coding because we have sequences of redundant sequences of numbers (0,1,-1), RLE will represent these coefficients into sequence of (Run, Length) strings, Since the DCT coefficients placed near the DC coefficient have, in most cases, larger values than other coefficients values, so the first five coefficients are left as its, while the remaining 59 coefficients will represent by using RLE [9].

- Shift Coding

Shift coding technique was used to encode the output of RLE, taking into consideration that we have long runs of zeros. Shift coding method is used to encode the Run Length codes.

Here the first five coefficients are left as they are and they converted directly to binary, the system gives them the required number of bits. The remaining coefficients are shift coded, the main idea of this coding method is to find the coefficient that is abnormally large between coefficients, the shift coding technique partition the large coefficient into smaller coefficients.

- Binary stream

After shift coding technique has been implemented, the image data is converted into a compressed sequence of binary digits (bits), some overhead information is also added to the binary sequence, these information are necessary, it includes the length of the binary sequence, the height and width of the image, this information is necessary in the de-coding stage.

▪ Implementation and results

We have chosen some bitmaps for test material by the proposed image compression system, two images for lena with different sizes were chosen in fig (3,4). The corresponding values of some compression efficiency are shown CR and BR. Fidelity measure MSE and PSNR was used to determine the difference between the compressed images and their original copies. Table (1) and table (2) show the results of compression system. Figures (5,6) show test samples with results :-

Table (1) show the effect of compression factor tested for Lena 128 × 128

	Quality factor	PSNR	MSE	File Size (byte)	CR	Bit Rate
1	0.4	46.21	0.94	23765	2.76	11.6
2	0.6	44.42	1.16	20865	3.14	10.19
3	0.8	43.01	1.37	18782	3.49	9.17
4	1.0	41.95	1.55	17114	3.83	8.36
5	1.2	41.01	1.73	15922	4.12	7.77
6	1.4	40.20	1.89	14806	4.43	7.23
7	1.6	39.53	2.04	13883	4.72	6.78
8	1.8	38.94	2.81	13088	5.01	6.39
9	2.0	38.43	2.31	12428	5.27	6.07
10	2.3	37.76	2.49	11485	5.71	5.61
11	2.5	37.32	2.62	10964	5.98	5.35
12	2.8	36.77	2.77	10270	6.38	5.01
13	3.0	36.45	2.87	9826	6.67	4.8
14	3.5	35.74	3.1	8954	7.32	4.37
15	4.0	35.16	3.3	8288	7.91	4.05
16	4.5	34.64	3.5	7734	8.47	3.78
17	5.0	34.20	3.69	7420	8.83	3.54
18	5.5	33.80	3.86	6851	9.57	3.35
19	6.0	33.45	4.01	6526	10.04	3.19
20	7.0	32.87	4.28	5994	10.93	2.93
21	8.0	32.37	4.5	5526	11.86	2.7
22	9.0	31.97	4.72	5165	12.69	2.52
23	10.0	31.61	4.91	4913	13.34	2.4

Table (2) show the effect of compression factor tested for Lena 256 × 256

	Quality factor	PSNR	MSE	File Size (byte)	CR	Bit Rate
1	0.4	45.60	1.02	100370	2.12	12.24
2	0.6	43.61	1.3	87529	2.43	10.68
3	0.8	42.1	1.56	78083	2.73	9.53
4	1.0	40.96	1.79	70223	3.03	8.57
5	1.2	39.99	2.0	63875	3.33	7.8
6	1.4	39.22	2.18	58454	3.64	7.14
7	1.6	38.58	2.34	53956	3.95	6.59
8	1.8	38.02	2.5	49684	4.29	6.06
9	2.0	37.55	2.63	46646	4.57	5.69
10	2.3	36.95	2.81	43308	4.92	5.29
11	2.5	36.58	2.93	40949	5.20	5.0
12	2.8	36.11	3.08	38214	5.57	4.66
13	3.0	35.85	3.16	36333	5.86	4.44
14	3.5	35.25	3.35	32671	6.52	3.99
15	4.0	34.77	3.52	30338	7.02	3.70
16	4.5	34.34	3.66	28485	7.48	3.84
17	5.0	33.95	3.8	26728	7.97	3.26
18	5.5	33.61	3.92	25382	8.39	3.1
19	6.0	33.31	4.03	24075	8.85	2.94
20	7.0	32.79	4.23	22016	9.67	2.69
21	8.0	32.37	4.4	20454	10.41	2.5
22	9.0	32.01	4.55	19196	11.10	2.34
23	10.0	31.71	4.68	18130	11.75	2.21

Conclusions

1- Using more than one coding techniques may enhances the coding performance to get a smaller sequence of binary digits. This depends on the selected coding techniques and the type of image used.
2- DCT is powerful in image Transform so its breaking fast the images into blocks with summarizing the overall 64 value in DC value perfectly without any errors.
3- The most powerful stage on the Compression system is quantization, it has dangerous influential on the data, we must choose an appropriate quantization formula and factors.

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Figure (3) original Lena 128 × 128

Figure (4) original Lena 256 × 256

Original(128×128) **Compressed**

Quality factor	**10.0**	**Bit Rate**	**2.4**
File size	**4913**	**PSNR**	**31.61**
CR	**13,34**	**MSE**	**4.91**

Figure (5) test sample

Original(256×256) **Compressed**

Quality factor	**10.0**	**Bit Rate**	**2.21**
File size	**18130**	**PSNR**	**31.71**
CR	**11,75**	**MSE**	**4.68**

Figure (6) test sample

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الخلاصة:-

إن المبدأ الرياضي للتحويل بدالة الجيب تمام باعتبارها دالة قوية يستخدم في مجالات واسعة ، ويستخدم كثيرا في برامج المعالجة الصورية ، في هذا البحث تم تقسيم الصورة الى ثلاثة اقنية لونية حيث ان القيم المترابطة للنقاط الصورية يمكن تمثيلها بدالة الجيب تمام بصورة منفصلة و يمكن معالجتها بصورة غير مرتبطة مع الاخرى أي ان القيم المحولة ليست لها علاقة بالقيم الاخرى لذلك يمكن ترميزها بصورة منفصلة مما يجعلها اسهل في بناء النظام الرياضي ان القيم المترابطة تم تحويلها باستخدام الترميز (Run-length) بينما استخدم (shift code) لترميز عامل التحويل (DC) وبقية العوامل الخمسة التي تم استثناؤها من (Run-length) ، في هذا البحث تم اقتراح الحفظ لاول خمسة عناصر من عوامل (DC) لاسترجاعها بدون أي اخطاء مؤثرة .النتائج التي حصلنا عليها من البحث كانت كالتالي (bitrates) كانت ضمن المدى (2.6 , 11.4) ونسبة الضغط (compression ratio) كانت ضمن المدى (13.34 , 2.76) وكانت نتائج القيم المعيارية (PSNR) ضمن المدى (46.21 , 31.61) لصورتين (Lena) اختبارية بمقاسات مختلفة (256×256 ,128×128) ، اما معامل (PSNR) فقد تم حسابه كمعدل لاقنية الالوان الثلاثة الاحمر والاخضر والازرق .