http://www.doi.org/10.62341/istj-vol38-2-si23

Received	**2026/04/29**	**تم استلام الورقة العلمية في**
Accepted	**2026/05/21**	**تم قبول الورقة العلمية في**
Published	**2026/05/22**	**تم نشر الورقة العلمية في**

Comparative Analysis of Image Compression using Discrete Cosine Transform and Huffman Coding

S. A. Aboukhres
Orcid.: 0000_0002_1849_9554

H. A. Ayad
Orcid.: 0000-0002-4802-6870

M. A. Sasi
Orcid: 0009-0009-5793-0923

Department of E&EE, Faculty of Engineering, University of Zawia, Zawia, Libya
Correspondence: S.aboukhres@zu.edu.ly

Abstract

Image compression using Transform Coding is investigated in this paper. The digital image is a matrix of different intensity value elements. In general, there are two different techniques for image compression, the first one is by directly implementing quantization and coding, while the second technique transforms the image from spatial to spectral (transform) domain first and then to be quantized and coded. Discrete Cosine Transform (DCT) proved to be the practical tool for this job. For quantization, two approaches are used, the uniform and nonuniform quantization. Comparison of the two approaches suggested our proposed quantization matrix. Appling the proposed matrix for different images gave better results for all related parameters, compared with the two tested approaches.

Keywords: Image Compression, Discrete Cosine Transform, DCT.

International Science and Technology Journal
المجلة الدولية للعلوم والتقنية

Volume 38 العدد
Part 2 المجلد

المجلة الدولية للعلوم والتقنية
International Science and Technology Journal
ISTJ

Comparative Analysis of Image Compression using Discrete Cosine Transform and Huffman Coding

http://www.doi.org/10.62341/istj-vol38-2-si23

دراسة تحليلية لضغط الصورة باستخدام تحويلة جيب التمام مع التكمية وشفرة هوفمان

صالح ابوخريص
Orcid.: 0000_0002_1849_9554

هشام عياد
Orcid: 0000-0002-4802-6870

محمود ساسي
Orcid: 0009-0009-5793-0923

قسم الهندسة الكهربائية والالكترونية، كلية الهندسة، جامعة الزاوية، الزاوية، ليبيا
S.aboukhres@zu.edu.ly

الملخص

ضغط الصورة باستخدام ترميز التحويل مع تحويلة جيب التمام هو موضوع بحث هذه الورقة. الصورة الرقمية هي مصفوفة تختلف عناصرها باختلاف شدة الإضاءة. يصوره عامة، هناك طريقتين لضغط الصورة، الطريقة الاولى تتعامل مباشرة مع الصورة في عملية التكمية والتشفير، اما الطريقة الثانية فإنها تقوم على تحويل الصورة من المجال المكاني الى المجال الطيفي اولا ثم تأتي عملية التكمية والتشفير، هناك أكثر من تحويلة تستخدم في هذا المجال حيث اثبتت تحويلة جيب التمام المنفصلة تميزها وذلك في قدرتها على اعداد الصورة لعملية الضغط. تم استعمال طريقتين للتكمية وهما التكمية المتناظرة والغير متناظرة. مقارنة النتائج المختلفة دفعنا لتصميم مصفوفة تكمية جديدة، باستعمال هذه المصفوفة ومقارنة النتائج تبين انها تعطي نتائج أفضل لكل المقاييس المطلوبة مقارنة بالطرق المستعملة في هذا البحث.

الكلمات المفتاحية: ضغط الصورة، تحويلة جيب التمام المنفصلة DCT

1- Introduction:

Image compression is a process that reduces the size of an image file while preserving its visual quality as much as possible, so that it takes less space on computer and can be shared faster over the

http://www.doi.org/10.62341/istj-vol38-2-si23

internet. Different techniques are used for this gool, some of them are lossy and others are lossless [1]. An image compression technique is verbally expressed to be the best when it contains less average code length, encoding and decoding time and provides more compression ratio [2,3]. Depending on the techniques used, there are two types of image compression [4]:

First- Predictive Coding (PC) working on spatial domain. Pixel values are predicted based on neighboring pixels and only the prediction error is encoded.

Second- Transform Coding (TC): The image is transformed to the spectral (transform) domain first to be compressed and this type is the field of this article.

A C++ program was built for doing the job in a sequence of the following steps:

♦ Loading the test image to be compressed
♦ Select sub-images of 8x8 pixels
♦ Find discrete cosine transform of each sub-image
♦ Applying the quantization operation for each coefficient of the transformed sub-image.
♦ Count repetitions of samples and its probability.
♦ Inverse transform the sub-image.
♦ Repeat with all sub-images and reconstruct the compressed image
♦ Mean Squared Error (MSE), Peak signal to Noise Ratio (PSNR), entropy, Average Codeward length (ACL) and Compression ratio (CR) are found using the following equations.

$$MSE = \frac{1}{MN}\sum_{i=0}^{M-1}\sum_{j=0}^{N}[x(i,j) - \hat{x}(i,j)]^2 \quad (1)$$

$$PSNR = 10log_{10}\left(\frac{255^2}{MSE}\right)(dB) \quad (2)$$

$$Entropy = -\sum_{i=0}^{N-1} Pro\ (i) * log2\big(Pro(i)\big) \quad (3)$$

$$CR = \frac{Number\ of\ original\ bits}{Number\ of\ compressed\ bits} \quad (4)$$

The Average Codeword Length (ACL) and its formula will be explained in the following sections.

http://www.doi.org/10.62341/istj-vol38-2-si23

2- Background:

In general, transform coding is a lossy technique, however, it can be arranged to produce a small acceptable error. The techniques used in transform coding are as follows [5]:

2.1- Transformation:

Reforming the image from spatial to spectral domain using one of different transforms where discreate cosine and wavelet transforms proved to be the most efficient [4,11], the discrete cosine transform was used in this work.

2.2- Quantization:

There are two methods of quantization used for image compression. To quantize the coefficients of the spectrum matrix, either uniformly, using one constant (step size) value, or non-uniform quantization using a matrix of different values is used. The standard S.JPEG matrix, as shown below, is used for non-uniform quantization where each coefficient of the transformed image matrix is rounded according to the related element of the quantization matrix [6]. In uniform quantization all coefficients are rounded according to the same constant (step size) value.

$$S.JPEG = \begin{bmatrix} 16 & 11 & 10 & 16 & 24 & 40 & 51 & 61 \\ 12 & 12 & 14 & 19 & 26 & 58 & 60 & 55 \\ 14 & 13 & 16 & 24 & 40 & 57 & 69 & 56 \\ 14 & 17 & 22 & 29 & 51 & 67 & 80 & 62 \\ 18 & 22 & 37 & 56 & 68 & 109 & 103 & 77 \\ 24 & 35 & 55 & 64 & 81 & 104 & 113 & 92 \\ 49 & 64 & 78 & 87 & 103 & 121 & 120 & 101 \\ 72 & 92 & 95 & 96 & 112 & 100 & 103 & 99 \end{bmatrix} \quad (5)$$

2.3- Coding:

The final step involves encoding the quantized data efficiently, which is the main factor for compression. Different techniques of coding are used where the most often, for image compression, are [4-7]:

2.3.1- Huffman Coding: A lossless coding algorithm, assigns shorter codes to frequently occurring values and longer codes to less

http://www.doi.org/10.62341/istj-vol38-2-si23

common ones. Most often, Huffman code is used after quantization producing a lossy system.

2.3.2- Run-Length Encoding: A lossless scheme, compresses sequences of repeated values as for example storing a row of 10 zeros as (0 x 10) instead of writing each zero individually. To get coefficients in a sequence, the coefficients matrix is rearranged in a ZegZag order giving a string of the coefficients.

2.4- Steps of Compression

As shown in Fig.1, below, in transform coding, the input image is divided to subblocks of 8x8 pixels, then each subblock is transformed, quantized and coded alone, finally, the subblocks are collected together to represent the comprised image [8,9,10].

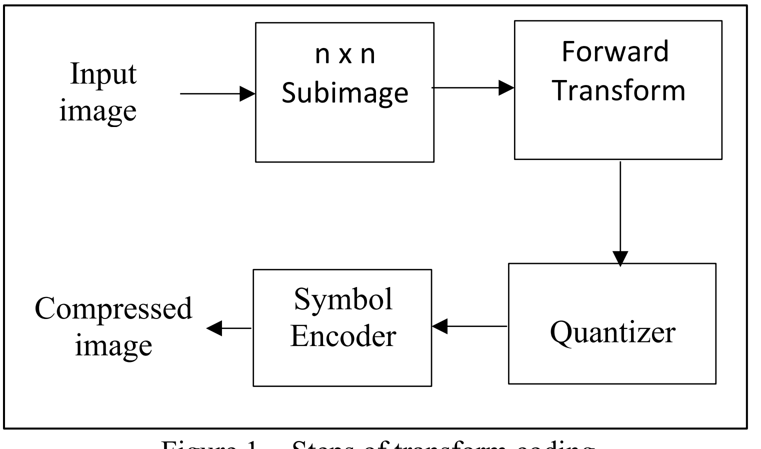


Figure 1- Steps of transform coding

Reconstruction of the image is a reverse operation to compression, starts with decoding the samples to be inverse transformed, then merging each 8x8 sub-image to build the reconstructed image.

Two commonly used gray scale test images were used in this analysis see figure (2, 3):

1- Image Women (mean = 126)
2- Image Peppers (mean = 119)

International Science and Technology Journal
المجلة الدولية للعلوم والتقنية
Volume 38 العدد
Part 2 المجلد

http://www.doi.org/10.62341/istj-vol38-2-si23

1- Results:

The following table presents the results of applying the procedure on the test image Women for four cases.

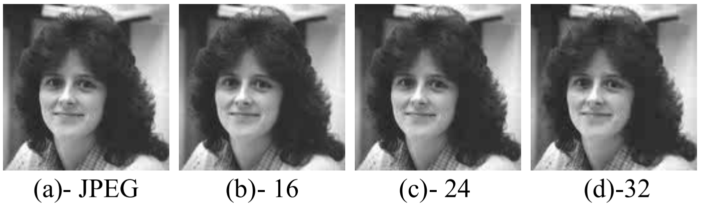
Table.1- Results of compressing image Women

	S-JPEG	Size =16	Size = 24	Size = 32
MSE	21.12	10.76	19.22	28.08
PSNR	34.5	37.1	35,3	33.6
CR	7.9	7.8	8.15	8.66
Entropy	1.61	1.54	1.34	1.12
ACL	2.57	2.4	2.1	1.87
# Samples	293	139	96	76
# Zeros	13984	13070	19284	14496

As shown in table-1, the higher the number of samples the longer Huffman code and longer Codewords, as in the case of S-JPEG, the number of different samples are 293 repeating 2400 times (16384 – 13984) where 16384 is the total number of coefficients (128x128). Each sample has it's own probability of occurrence and code word including the sample zero. We can find the average length of the codeword (ACL) using the following formula:

$$ACL = \sum_{i=1}^{293} P(s_i)L(s_i) \qquad (6)$$

Where the entropy is the optimum case for average code word length ACL



(a)- JPEG (b)- 16 (c)- 24 (d)-32

Figure.2- Women compression using JPEG for (a) and different Step sizes for (b, c and d)

http://www.doi.org/10.62341/istj-vol38-2-si23

The same procedure was applied for the image Peppers and the following table presents the obtained results.

Table2- Results of compressing image Peppers

	a- S-JPEG	b-Size= 16	c-Size =24	d- Size =32
MSE	33.64	13.00	24.57	37.2
PSNR	32.86	37	34.2	32.43
CR	6.7	6.3	7.45	8.16
Entropy	2.182	1.941	1.543	1.299
ACL	3.13	2.9	2.5	2.25
# Sampls	318	128	88	3012
# Zeros	13042	11590	12695	13372

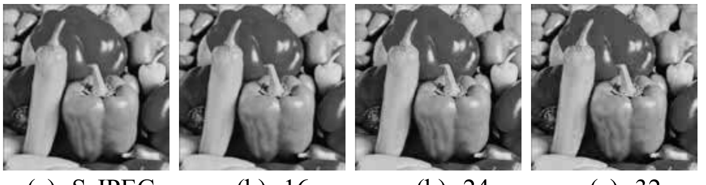

(a)- S-JPEG (b)- 16 (b)- 24 (c)- 32

Figure3- Peppers compression using S-JPEG for (a) and different Step size for (b, c and d)

From the above obtained results for Entropy and number of samples, it is clear that having many different values of the quantization matrix elements will yield a long code with long codewords resulting in more bits to be stored or transmitted [10]. At the same time, using one step size has its disadvantages, where using one small step size produces too long code, while using a higher value, results in high value of MSE and low value of PSNR

A new quantization matrix was proposed, the elements of which consist of only three different values, where the three values are multiples of 8 for adapting the quantization output. The proposed matrix is as shown below.

http://www.doi.org/10.62341/istj-vol38-2-si23

$$\text{Proposed Q-matrix} = \begin{bmatrix} 16 & 16 & 16 & 16 & 32 & 32 & 32 & 32 \\ 16 & 16 & 16 & 32 & 32 & 32 & 32 & 32 \\ 16 & 16 & 32 & 32 & 32 & 32 & 32 & 32 \\ 16 & 32 & 32 & 32 & 32 & 32 & 32 & 32 \\ 32 & 32 & 32 & 32 & 32 & 32 & 32 & 96 \\ 32 & 32 & 32 & 32 & 32 & 32 & 96 & 96 \\ 32 & 32 & 32 & 32 & 32 & 96 & 96 & 96 \\ 32 & 32 & 32 & 32 & 96 & 96 & 96 & 96 \end{bmatrix} \quad (7)$$

Table.3, below, presents a comparison between S-JPEG and Proposed quantization matrix for compression of the two test images. It is clear, that, the proposed quantization matrix gives better results of Mean Squared Error (MSE), higher values of Peak Signal to Noise Ratio (PSNR and compression ratio CR), compared with S-JPEG, By comparing the results of the tow images. we note the effect of image structure on compression.

Table.3- Comparison of JPEG and Proposed Q-matrices results

	Image women		Image Peppers	
	S-JPEG	**Propose**	**S-JPEG**	**Propose**
MSE	**21.12**	**20.48**	**33.67**	**28.90**
PSNR	**34.9**	**35.02**	**32.86**	**33.52**
CR	**7. 6**	**8.49**	**6.7**	**7.56**
Entropy	**1.61**	**1.1734**	**2.18**	**1.58**
ACL	**2.57**	**2.13**	**3.13**	**2.53**
# Samples	**293**	**139**	**318**	**128**
#Zeros	**13984**	**14496**	**13042**	**13027**

2- Conclusion

From the results, shown above, dividing by different values produces much more samples or coefficients which need to be coded resulting in a lengthy code and more lengthy code words, on the other hand, dividing by one value (step size) will produce only multiples of that step size, where, the higher value of step size the lower number of samples. To avoid losing some information of lower frequency coefficients, a new quantization matrix of only three different values was proposed. The results of using the proposed quantization matrix are better than those of using one step size (uniform) or of using many step sizes (nonuniform),

http://www.doi.org/10.62341/istj-vol38-2-si23

3- References

[1] A.M. Raid et al (April 2014) "jpeg image compression using discrete cosine transform – A survey" International Journal of Computer Science& Engineering Survey (IJCES)Vol.5, No. 2.

[2] B. Jahne (2005), "Digital image processing", springer -verlag berlin Heidelberg.

[3] C. A. Christopoulos et al (1993), "Discrete cosine transform coding of images "DSP & CAES conference, July 1993, Nicosia, Cyprus.

[4] Elakkiya S, (2021) "Comprehensive review on lossy and lossless compression techniques". J Inst Eng India Ser B 103(3):1003–1012. https://doi.org/10.1007/s40031-021-00686-3

[5] Hussain AJ, et al, (2018) "Image compression techniques: a survey in lossless and lossy algorithms". Neurocomputing 300:44–69. https://doi.org/10.1016/j.neucom.2018.02.094.

[6] M. Aiswarya (December 2024) "A Review on Image Compression Techniques" IJIRT, Volume 11. Issue 7, ISSN:2349-6002.

[7] M. D. Atiqur Rahman et al (2019), "Lossless Image Compression Techniques: A State -of-the Art Survey", Symmetry.

[8] R. Gonzalez et al, (2002). "Digital Image Processing". 2nd ed, Upper Saddle River NJ, USA, Printice Hall Inc

[9] S. Aboukhres et al (2017) "A Novel Method for Optimizing the Ratio of Image Compression", STA'2017, December 21-23, Monastir, Tunisia.

[10] S. Aboukhres (2010) "A Noval Sampling Scheme for Image Compression" 18th Mediterranean Conference on Control and Automation. Marrakech, Marocco, June 23-25, 2010.

[11] Xinpeng Zhang. (2019). "Lossy Compression and iterative Reconstruction for Encrypted Image", IEEE Transactions On Information Forensics And security, vol. 6, No.1, pp. 53-58,.