Suggested hybrid Transform Technique for image compression

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Abstract

Digital images are used in several domains. Large amount of data is necessary to represent the digital images such data needs large transmission bandwidth for the transmission over the network and also require storage capacity. Hence the data in the images should compressed by extracting only the visible elements. The image compression technique can reduce the storage and transmission costs. Image compression techniques should also maintains the quality of images. This paper proposes hybrid image compression technique which combines Discrete Cosine Transform (DCT) with Slantlet Transform (SLT). Several methods such as Discrete Cosine Transform (DCT), is used for compressing the images. But, these methods contain some artifacts. In order to overcome this difficulty and compress the image efficiently, a combination of DCT and SLT is proposed. Firstly Transform the image to frequency domain by applying SLT and decompose it into three levels, then DCT is applied on LL3.The results indicate that hybrid (SLT-DCT) technique offers superior compression performance compared to hybrid (DWT-DCT) based approaches. Their performance is evaluated in terms of Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE), UQI, SSIM and Compression Ratio (CR).

Keywords: Image compression, Discrete Cosine Transform, Discrete wavelet Transform, Slantlet Transform, CR, PSNR, MSE, UQI, SSIM.

الخـلاصـة

تُستخدم الصور الرقمية في مجالات عديدة.وتتطلب كم كبير من البيانات الضرورية لتمثيلها،وهذه البيانات تتطلب مساحة خزنية كبيرة وأيضا نطاق ترددي عالي عند أرسالها عبر الأنترنت.لذلك يجب توفير تقنيات تقوم بضغط الصور لتقليل حجمها وكلفة نقلها. وأيضا يجب أن تحافظ هذه التقنيات على جودة الصورة المضغوطة. في هذا البحث تم أقتراح تقنية هجينة لضغط الصور بأستخدام التحويل الجيبي المتقطع (DCT) وتحويل الأنحدار المائل(SLT) .العديد من التقنيات السابقة أستخدمت التحويل الجيبي المتقطع في ضغط الصور ولكن هذه التقنيات كانت تحتوي على تشوهات مربعة في الصورة المضغوطة الناتجة من تقسيم الصورة الى مصفوفات مربعة.ومن أجل تجاوز هذه العقبة وضغط الصور بصورة كفوئة تم أقتراح تحويل هجين يجمع بين كل من التحويلين السابقين حيث أن تحويل الأنحدار المائل له القدرة على تحويل الصورة بأكملها دون الحاجة الى تقسيمها.يتم أولاً تحويل الصورة الى المجال الترددي بتطبيق ثلاث مستويات SLT بعد ذلك أختيار النطاق الفرعي LL3 وتطبيق DCT عليه.تمت مقارنة نتائج البحث مع تحويل هجين أخرهو التحويل الجيبي المتقطع-تحويل المويجي المتقطع (DWT-DCT) حيث أظهرت النتائج كفائة تحويل SLT-DCT المقترح الهجين من حيث نسبة الضغط العالية وجودة الصور المضغوطة.بأستخدام مقاييس التشوه PSNR، MSE، QUI، SSIM ونسبة الضغط CR للمقارنة بين الطرائق المختلفة.

ألكلمات المفتاحية: ضغط الصورة، تحويل جيب التمام المنفصل، تحويل المويجات المنفصل

1. Introduction

Common characteristics of most images are that the neighboring pixels are correlated. Therefore the most important task is to find a less correlated representation of image. The fundamental components of compression are reduction of redundancy and irrelevancy. Redundancy reduction aims at removing duplication from the image. Irrelevancy reduction omits parts of the signal that will not be noticed by the signal receiver namely the human visual system (HVS). Three types of redundancies can be identified: spatial redundancy, spectral redundancy and temporal redundancy. In still image, the compression is achieved by removing spatial redundancy and spectral redundancy [1]. Image compression involves reducing the size of image data files, but retaining necessary information. Two types of image compression technique lossy and lossless, lossless compression is used with the applications that don't accepts any difference between the original and compressed data such as medical images [2]. Lossy methods are suitable for natural images such as photographs in applications where minor loss of fidelity is acceptable to achieve reduction in bit rate [3]. Transform coding is the most successful and pervasive technique for lossy compression, transformed from the spatial domain to the frequency domain. The idea of using transform coding is to transform the image into a new domain, where the image coefficients are less correlated [4]. An effective transform will concentrate useful information into a few low-frequency transform coefficients; the HVS is more sensitive to energy with low spatial frequency than with high spatial frequency. Therefore, compression can be achieved by quantizing the coefficients, so that important coefficients (low-frequency coefficients) are transmitted and the remaining coefficients are discarded [5].

2. Related Works

Numerous researches have been proposed by researchers for the image compression process. In this section, a brief review of some important contributions from the existing literature is presented.

Panrong, X. 2001[6] studied image compression with wavelet transform. As a necessary background, the basic concepts of graphical image storage and currently used compression algorithms are discussed. The mathematical properties of several types of wavelets are covered and the Embedded Zero tree Wavelet (EZW) coding algorithm was introduced.

Wasan ,K. S. 2004 [7],This thesis was concerned with a certain type of compression that uses hybrid technique which combines differential pulse code modulation (DPCM) with wavelet transform .The wavelet transform is applied to the difference frame instead of direct application to the original images because the different signal is almost nearly stationary.

Husen, H. H. 2006, [8] studied image compression with multiwavelets transform based image encoder. A compression example verified with wavelet-based transform once, then with a multiwavelets-based transform on the same image. both wavelet and multiwavelets are applied to each block of the image. Such an implementation shows that Multiwavelets method is better to the wavelet method in terms of image quality. After testing several methods of multiwavelet transforms computation for image compression the mixed method was chosen.

Mohammed Hussien Miry, 2008 [9], studied new transform "improved Ridgelet Transform, he used SLT instead of DWT in the Ridgelet. A comparison was made with compression using Ridgelet transform for different images. A high quality image has been achieved for natural images. Simulation results indicate that the improvement Ridgelet transform offers superior and faster compression performance compared to the Ridgelet transform based approaches.

Ali Hussien mary, 2010 [10], used Differential pulse code modulation (DPCM) in slantlet transform and Run Length Code for image compression. Apply SLT on each component in the color image (after applying color space conversion from RGB to YCbCr)and encoding Y component by DPCM and encoding Cb and Cr with RLC. The compression ratio and Peak Signal to Noise Ratio (PSNR) are used as measurement tools. When comparing the proposed approach with other compression methods Good result is obtained.

Nushwan Y. Baithoon 2011 [11], proposed a hybrid transform based on (DWT) and (DCT) with a new enhancement method, which is the sliding run length encoding (SRLE) technique, to improve the compression. First step involves transforming the color components of the image from RGB to YUV planes to acquire the advantage of the existing spectral correlation and consequently gaining more compression. DWT is then applied to the Y, C_b and C_r color space information giving the approximate and the detail coefficients. The detail coefficients are quantized, coded using run length encoding (RLE) and SRLE. The approximate coefficients were coded using DCT, since DCT has superior compression performance when image information has poor power concentration in high frequency areas. This output is also quantized, coded using RLE and SRLE. Test results showed that the proposed DWT DCT SRLE system proved to have encouraging results in terms of (PSNR), Compression Factor (CF) and execution time when compared with some DWT based image compressions.

Moh'dAli Moustafa Alsayyh, Dzulkifli Mohamad, Waheeb abu-ulbaa 2013 [12], proposed hybrid technique between DCT & DWT. The first step is segment the image into background and foreground based, then divide the image into 8x8 blocks, implement the DCT coefficients for each block. & quantize the DCT coefficients based on quantization table, and transform the output image using DWT and apply another quntization table. PSNR and MSE is better than the old algorithms and due to. Hence overall result of hybrid compression technique is good.

Deepak Kumar Jain, **Devansh Gaur**, **Kavya Gaur**, **Neha Jain** [13] 2014, presents medical image compression technique using DCT and Huffman encoding. First divide the image into blocks and apply DCT to each block, quantize the DCT coefficients and encode it using Huffman encoding. This technique is better performance compared with many others compression techniques.

Zhou, Xiao, Yunhao Bai, and **Chengyou Wang** [14] 2015, they proposed image compression scheme, based on (DCT). It's a hybrid method, which combines vector quantization (VQ) and differential pulse code modulation (DPCM). This scheme begins with transforming image from spatial domain to frequency domain using DCT. Then the block data is transformed into a vector according to zigzag order, and then truncated. After that, the vector is split into DC coefficient and AC coefficients. After scale quantization, DC coefficient is coded using DPCM. AC coefficients are coded using multistage vector quantization (MSVQ). Then, entropy encoding is performed on index-tables and DC part, separately. The experimental results show that, compared to conventional VQ and DCTVQ schemes, proposed scheme has a better performance.

Karthikeyan T, Thirumoorthi C. [15] 2016, they compared five image compression techniques to compress medical images. They used Fourier transform, DCT, WHT, KLT, and the proposed Sparse Fast Fourier Transform. The experimental results show that.

3. Theoretical side:

In this section, DCT, DWT, SLT and Hybrid DCT-SLT techniques are discussed.

3.1 Discrete Cosine Transform(DCT):

It's the basis for many image and video compression algorithms, especially the baseline JPEG and MPEG standards for compression of still and video images respectively .The DCT has the property of compaction the most visually significant information of the image into few low frequency coefficients in the upper left side and requires less computational resources [16].there is mainly two type of DCT: 1D DCT and 2D DCT for N x N input signal defined as follow: [17]

$$D_{DCT}(i,j) = \frac{1}{\sqrt{2N}} B(i)B(j) \sum_{x=0}^{N-1} \sum_{y=0}^{N-1} M(x,y) \cos\left[\frac{2x+1}{2N} i\pi\right] \cos\left[\frac{2y+1}{2N} j\pi\right] \quad \dots (1)$$

where

$$B(u) = \begin{cases} \frac{1}{\sqrt{2}} & if \quad u = 0 \\ 1 & if \quad u > 0 \end{cases}$$

M (x,y) is the input data of size x×y. The input image is divide into 8X8 blocks then applying the 2D-DCT on the blocks, DCT coefficients are then quantized using an 8×8 quantization table where parts of compression actually occur, the less important frequencies are discarded, hence the use of the lossy. Then the most important frequencies that remain are used retrieve the image in decomposition process [18]. **Figure.1** illustrate the whole procedure.

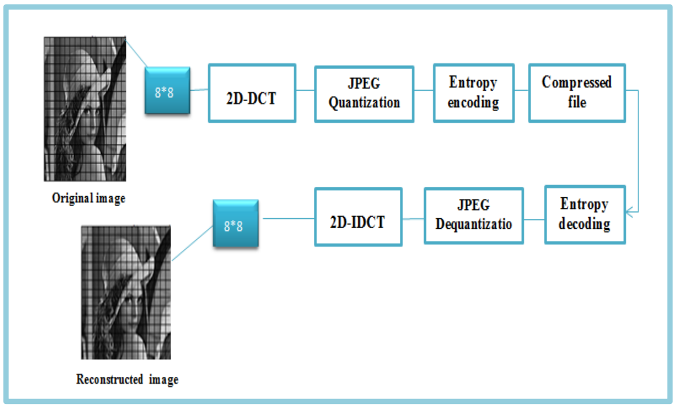


Figure (1) Block diagram of the JPEG-based DCT

3.2 Discrete Wavelet Transform (DWT):

Discrete Wavelet Transform (DWT) is widely used for image compression .wavelet analysis use multiresolution analysis (MRA) technique of signals [19] that divide information of image into approximation and detail parts, were set of high pass filter & low pass filter applied to image. if the signal is put through high pass filter and low pass filter then the signal is decomposed into two parts a detail part (high frequency) and the approximation part (low frequency), the sub-signals produced from low filters will have highest frequency equal to half of the original according to Nyquist sampling this change in frequency range means that only half of original samples need to kept in order to perfectly reconstruct the signal. At every level, four sub-images are got: one approximation and three detail (LL, LH, HL, and HH) as illustrated in figure (2) [20]. Then all the coefficients are discarded, except the LL coefficients that are transformed into the second level. These coefficients are then passed through a constant scaling factor to achieve the desired compression ratio. The DWT is usually implemented in form of an iterated filter bank, where a tree structure is utilized. Hence, the component filter branches rely on product form of implementation [15]. Following figure 3 is an illustration of Two-scale Filter bank and an Equivalent of DWT. Here, F[z] is the high frequency component, and H[z] is the low frequency component. For data reconstruction, the coefficients are rescaled and padded with zeros, and passed through the wavelet filters.

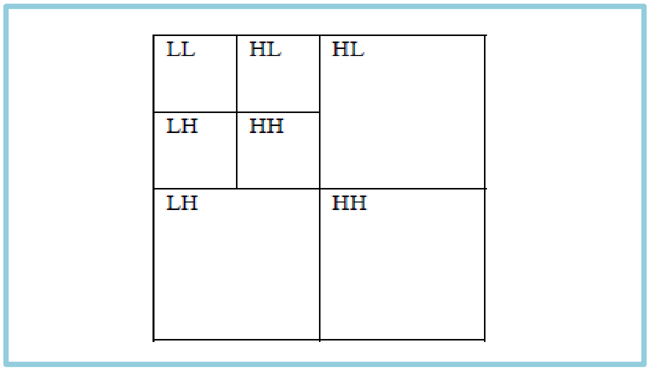


Figure (2) two level decomposition wavelet transform

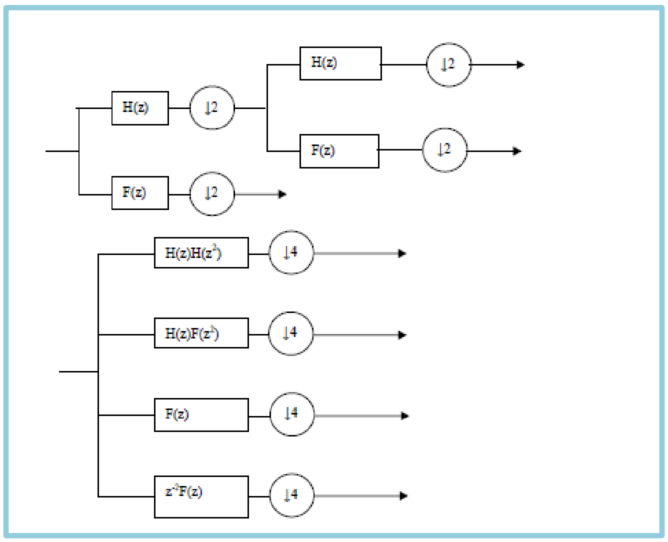


Figure (3) two-scale filter bank and an equivalent

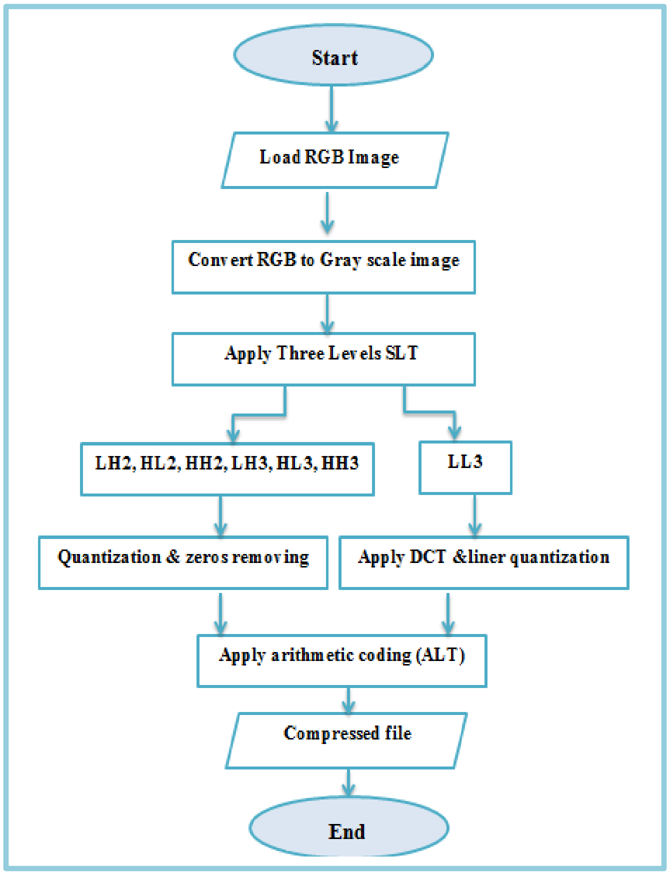
3.3 Slantlet Transform (SLT):

The Slantlet transform (SLT) is a relatively new multi-resolution technique base on DWT. actuality, it is an orthogonal DWT with two zero moments and it provides better time localization than DWT [19].DWT requires a large number of iterations to achieve a discrete time basis for an optimal result [18]. Therefore Slantlet transform (SLT) is adopted in this paper because it is not based on iterated filter bank; instead, it is based on a filter bank structure where different filters are used for each scale; hence, the component filter branches do not rely on any product form of implementation and it possesses extra degrees of freedom. For a two-channel case the Daubechies filter is the shortest filter which makes the filter bank orthogonal and has K zero moments. For K=2 zero moments the iterated filters lengths equal 10 and 4 but the Slantlet filter bank with K=2 zero moments has filter length 8 and 4. Thus the two-scale Slantlet filter bank has a filter length which is two samples less than that of a two-scale iterated Daubechies-2 filter bank. This difference grows with the increased number of stages. Each filter bank has a scale dilation factor of two and provides a multi-resolution decomposition. The Slantlet filters are piecewise linear. Even though there is no tree structure for Slantlet it can be efficiently implemented like an iterated DWT filter bank. Therefore, computational complexity of SLT is of the same order as of DWT, but SLT gives better performance in de-noising and compression of the input signals [21].

4. The proposed hybrid technique:

The purpose of the hybrid SLT-DCT technique is to exploit the properties of both SLT and DCT. The technique begins with selecting original image of size 512×512 or any resolution and converted into the transform domain using three level of SLT, in each of these three levels low frequency coefficients (LL) are passed to the next stage where the high frequency coefficients (HL, LH, and HH) are quantized and remove zeros from it. Then DCT is applied to LL3 of the third level to achieve a higher compression liner quantization (uniform) is performed. In this stage, many of the higher frequency components are rounded to zero. The quantized coefficients are then encoded using Arithmetic coding (ALT).Then the image is reconstructed by following the inverse procedure. During inverse SLT, zero values are padded in place of detailed coefficients [22]. The block diagrams are given in Fig. 4 & 5 below that represents the flow of the abovementioned methodology. The high frequency component is reduced using quantization factor its default range between [0.01 - 0.1] the reconstructed image will be degraded (blurred) if Factor greater than or equal to 0.1, then eliminating zeros form each sub-band, and compress each sub-band by Arithmetic Coding. DCT is applied on LL3 sub-band its component is reduced using liner quantization factor with range [0.005-0.01] its default value "0.01" is divided by low frequency LL3 component, and then compress it by Arithmetic Coding.

Figure (4) A flowchart of the proposed hybrid technique



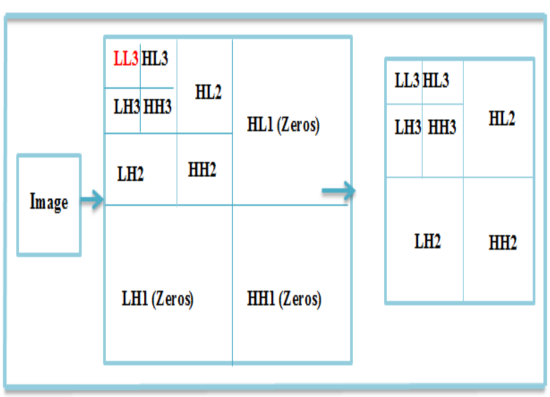


Figure (5) a

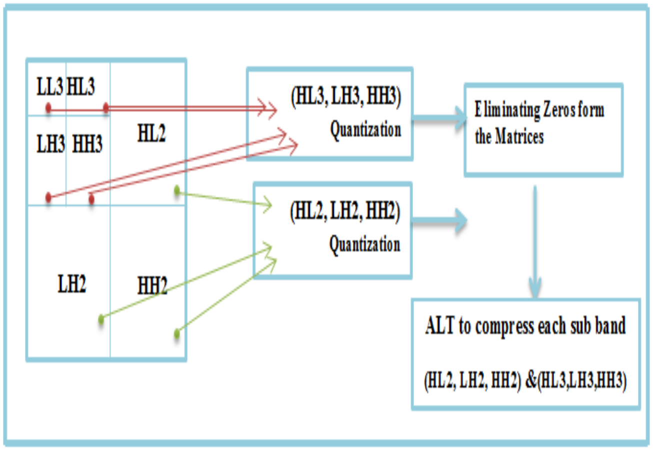


Figure (5) b

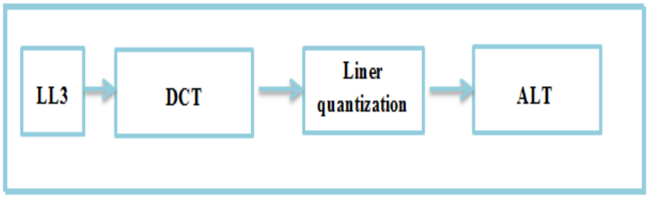


Figure (5) c – Compression technique

5. Performance evaluation parameters

1. **Image quality assessment based on error sensitivity**

   A natural way to determine the fidelity of a recovered image is to find the difference between the original and reconstructed values. Two popular measures of distortion are:

1.1 MSE: mean squared error it is another performance evaluation parameter of Image Compression Algorithms. It is an important evaluation parameter for measuring the quality of compressed image. It compares the original data with reconstructed data and then results the level of distortion. The MSE between the original data and reconstructed data is:

$$MSE = \frac{1}{m\,n}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[I(i,j) - K(i,j)]^2 \quad \dots (2)$$

Where I (i,j) is the original image of size i×j, K(i,j) is the reconstructed image of size i×j.

1.2 PSNR: It is the most popular tool for the measurement of the compressed image and video. It is simple to compute. The PSNR in decibel is evaluated as follows [23]:

$$PSNR = 10 \cdot \log_{10}\left(\frac{MAX_I^2}{MSE}\right) \quad \dots (3)$$

2. **Compression Ratio**

The most popular metric of performance measure of a data compression algorithm is the compression ratio. It is defined as the ratio of the number of bits to represent the original data to the number of bits to represent the compressed data [24].

$$CR = \frac{\text{uncompressed data}}{\text{compressed data}} \qquad \dots (4)$$

Sometimes the **space savings** is given instead, which is defined as the reduction in size relative to the uncompressed size:

$$saving\ space = \left(1 - \frac{Compressed\ size}{uncompressed\ size}\right) * 100\%$$

3. Image quality assessment based on structural similarity

3.1 Universal Quality Measure (UQI):

Wang and Bovik [25], developed a mathematical approach to calculate the image quality measure by having access to both the original image and distorted image as follows:

$$Q = \frac{\sigma_{xy}}{\sigma_x \sigma_y} \cdot \frac{2\overline{x}\overline{y}}{(\overline{x})^2(\overline{y})^2} \cdot \frac{2\sigma_x \sigma_y}{\sigma_x^2 + \sigma_y^2} \quad \ldots (5)$$

Where (x) is the base image intensity values and (y) is the distorted image intensity values with respected mean and variances:

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i \ldots (6) \quad , \quad \bar{y} = \frac{1}{N}\sum_{i=1}^{N} y_i \ldots (7) ,$$

$$\sigma_x^2 = \frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2 \ldots (8) ,$$

$$\sigma_y^2 = \frac{1}{N-1}\sum_{i=1}^{N}(y_i - \bar{y})^2 \ldots (9) ,$$

$$\sigma_x^2 = \frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})(y_i - \bar{y}) \ldots (10).$$

In this algorithm there is a sliding window of size 8x8 which will slide the 8x8 portions of distorted image on the corresponding areas of the base image and calculates Q in this Equation. This will provide a map of Qs and the average value of this map will provide us the quality measure as follows:

$$Q = \frac{1}{M}\sum_{j=1}^{M} Q_j . \quad \ldots (11)$$

where M is the number of steps depending on the size of the image. The higher values of *Q* may indicate a better quality for the distorted image.

3.2 Structural Similarity (SSIM):

Wang et_al [25,26] developed a Structural Similarity (SSIM) quality measure method which is considered as the full original image quality measure. In this method Wang improved the (UQI) and hence calculated the image quality measure as follows:

$$SSIm(x,y) = \frac{(2\bar{x}\bar{y} + c_1)(2\sigma_{xy} + c_2)}{(\bar{x}_x^2 + \bar{y}_y^2 + c_1)(\sigma_x^2 + \sigma_y^2 + c_2} \ldots (12)$$

In this algorithm C_1 & C_2 parameters are included, where $C1 = (K_1L)^2$ & $C_2 = (K_2L)^2$. Here L is the dynamic range of the pixel values (255 for 8- bit gray scale images), and K>1 is a small constant. Also x is the original image and y is the distorted image intensities. This algorithm uses 8x8 windows and will make a map of the SSIM values. The average of the obtained SSIM map will provide the quality measure as follows:

$$MSSIM(X,Y) = \frac{1}{M}\sum_{j=1}^{M} SSIM(x_j, y_j). \quad \ldots (13)$$

Where M is the number of steps depending on the size of the image. The higher values of MSSIM will provide a better quality of the distorted images.

6. Experimental results

The proposed (SLT-DCT) technique and (DWT-DCT) are implemented using Matlab 2016. The techniques applied on gray scale images with dimension (512*512) and (256*256). Original and reconstructed images are also shown in table 5. Table No.1 shows different compression ratio and the PSNR in dB of different gray images. The proposed technique increased the CR, PSNR, SSIM and UQI over the other technique (DWT-DCT). The results revealed that average PSNR value of more than 43dB was achieved, which is considered very high, the file size reduced from (786432 byte) to (29494 bytes) in the proposed technique and reduced to (46917 byte) in the other technique. In our work the time required to compute (SLT-DCT) is 16.085sec while in (DWT-DCT) is 33.624 sec, this means that the proposed technique is better than the other technique.

Table (1) CR, MSE and PSNR values obtained using hybrid (DWT-DCT) & the proposed technique (SLT-DCT) for image dimension (512*512).

Image	Transform	Uncompressed file size	Compressed file size	CR	MSE	PSNR
1	DWT-DCT	786432 bytes	46917 bytes	16.762	18.6384	35.4607
	Proposed(DCT-SLT)	786432 bytes	29494 bytes	26.664	7.7829	39.2534
2	DWT-DCT	786432 bytes	35859 bytes	21.931	10.6248	37.9016
	Proposed(SLT-DCT)	786432 bytes	22125 bytes	35.544	3.0899	43.2654
3	DWT-DCT	786432 bytes	31594 bytes	24.891	12.3557	37.2461
	Proposed(SLT-DCT)	786432 bytes	25751 bytes	30.539	3.0438	43.3307

Table (2) SSIM ،UQI and saving space values for image dimension (512*512).

Image	Transform	SSIM	UQI	Saving Space
1	DWT-DCT	0.86900	0.70436	94%
	Proposed(SLT-DCT)	0.9383	0.82895	96%
2	DWT-DCT	0.88967	0.68354	95%
	Proposed(DCT-SLT)	0.94292	0.80999	97%
3	DWT-DCT	0.90848	0.70882	95%

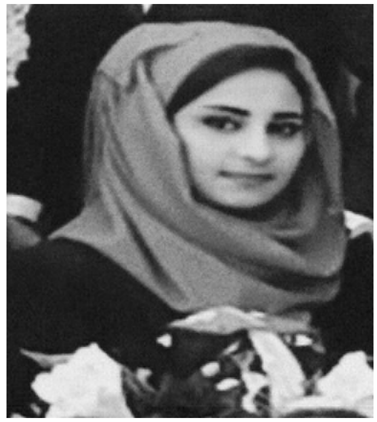
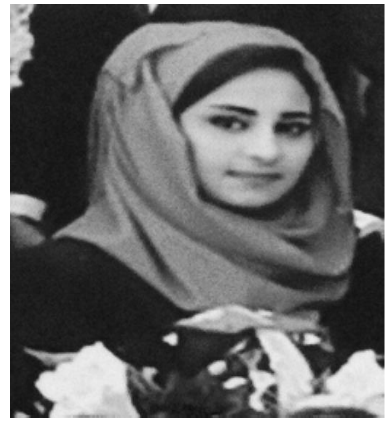
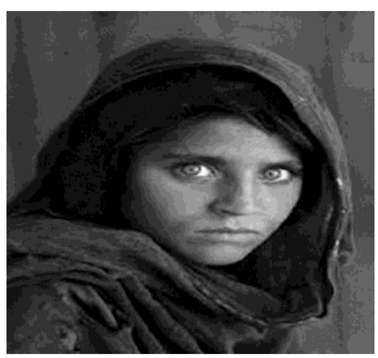
Table (3) CR, MSE and PSNR values obtained using hybrid (DWT-DCT) & the proposed technique (SLT-DCT) for image dimension (256*256).

Image	Transform	Uncompressed file size	Compressed file size	CR	MSE	PSNR
1	DWT-DCT	196608 bytes	15381 bytes	12.782	28.5795	33.604
	Proposed(SLT-DCT)	196608 bytes	14036 bytes	14.007	11.5024	37.556
2	DWT-DCT	196608 bytes	14067 bytes	13.976	21.4319	34.854
	Proposed(SLT-DCT)	196608 bytes	11833 bytes	16.615	4.7238	41.421
3	DWT-DCT	196608 bytes	12923 bytes	15.213	21.483	34.843
	Proposed(SLT-DCT)	196608 bytes	12699 bytes	15.482	7.4334	39.452

Table (4) SSIM ،UQI and saving space values for image dimension (256*256).

Image	Transform	SSIM	UQI	Saving Space
1	DWT-DCT	0.81746	0.63198	92%
	Proposed(SLT-DCT)	0.93866	0.82229	92%
2	DWT-DCT	0.83945	0.70461	92%
	Proposed(SLT-DCT)	0.95597	0.90105	93%
3	DWT-DCT	0.82236	0.68424	93%
	Proposed(SLT-DCT)	0.94581	0.86725	93%

Table (5) compression of different gray image

Image	Original Image	SLT-DCT	DWT-DCT
1			
2			
3			

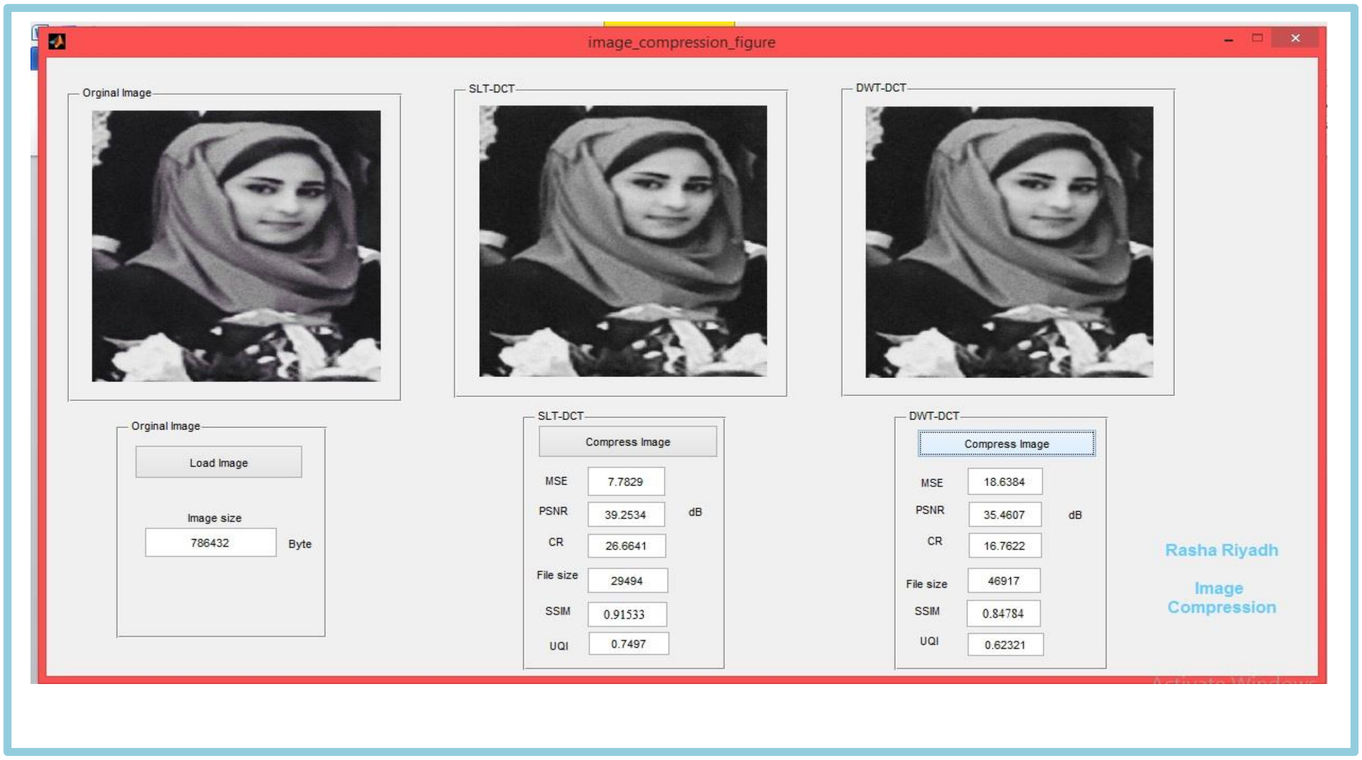


Figure (6): Compression Program interface

7-Conclusion

In this work the (SLT-DCT) technique has been applied for compression of gray images. The SLT is an orthogonal DWT and provides improved time localization than DWT. It uses different filter for each scale to get different information for input signal. It is observed from the results that the hybrid SLT-DCT algorithm for image compression has better performance in quality wise and performance wise compared to DWT-DCT. The performance comparison is done by considering the performance criteria (PSNR, MSE, UQI, SSIM and

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Compression Ratio). In general, it is observed that the accuracy of the reconstruction of the proposed technique is better than that the (DWT-DCT) Exhaustive computer results on different images indicate this trend. Thus it is, in general, concluded that the SLT based compression technique yields better performance compared to the DWT regarding the used images.

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