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A Novel Fused Image Compression Technique Using DFT, DWT, and DCT

Mohd Ali Moustafa Yousif Alsayyh
Faculty of Computing, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia

Dzulkifli Mohamad
Faculty of Computing, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia

Tanzila Saba
College of Computer and Information Sciences Prince Sultan University Riyadh 11586 Saudi Arabia

Amjad Rehman
College of Computer and Information Systems Al-Yamamah University Riyadh 11512 Saudi Arabia

Jarallah S. AlGhamdi
College of Computer and Information Sciences Prince Sultan University Riyadh 11586 Saudi Arabia

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Abstract. *Image compression processes moderate the number of bits essential to signify an image, which can improve the performance of systems during storage and transmission without compromising image quality. Accordingly, a new hybrid image compression technique has been suggested in this research. Three transform-based techniques discrete Fourier transform (DFT), discrete wavelet transform (DWT), and discrete cosine transform (DCT) have been combined for image compression to confer the good characteristics of these methods. The proposed method works for forfeiture compression and the attained results show that it works well compared to existing approaches. To test the level of compression, the quantitative measures of the peak signal-to-noise ratio (PSNR) & mean squared error (MSE) are used to ensure the effectiveness of the suggested system.*
Keywords: Multimedia signal processing; Data fusion; Image compression; Information visualization.

1. **Introduction.** In recent years, there has been widespread emergence of multimedia and therefore there is a growing requirement for images to be stored in large number and high quality [1-6]. One of the problems is that images of high quality generally have a large size. In order to resolve such issues, it is necessary to find some methods appropriate for the compression of images. In the compression process, the amount of data needed to represent a certain quantity of information is reduced [7-12]. In other words, the compression technique is aimed at eliminating the redundancy in data in such a way that an image of acceptable quality can be reconstructed [13-16].

In domain of image processing; image compression is highly demanded due to the fast advancement of communications, computer, and internet technology [17-20]. The information and data are transmitted via the internet, and the data, information, and images transmitted consume a large bandwidth and large storage space [21,22]. In order to resolve the storage and high-bandwidth communication issues, the computing community is in need of data compression techniques that do not compromise on quality of the images

[23, 24]. Additionally, image compression reduces the length of time required to direct images over the internet and lessens the size in bytes of the images [25-27].

Image compression techniques can be classified into two categories: lossy and lossless compression [28,29]. In the lossless compression method, the remodeled image is numerically duplicate of the original image. Losslessness is important in applications such as image archiving. The second type is lossy image compression, which is now used by most applications because it offers a higher compression ratio compared with lossless image compression [30, 31, 32].

The actual purpose of image compression is to use lowest number of bits without dropping necessary information in an image. Image compression is an important technology in digital communication and multimedia fields [33-36].

2. **Research Background.** Initially, Jasmine et al., [37] used wavelet and ridgelet to compress an image. Accordingly, the RGB image is altered to be a grayscale image and used the Gaussian filter to denoise it. Following denoising, Discrete Wavelet Transform (DWT) is applied to the denoised image and Finite Ridgelet Transform (FRT) is performed in order to obtain wavelet coefficients that result into a compressed and smaller image size. To obtain the original decompressed image, the opposite of FRT and DWT are applied. The result of the compressed image using the hybrid image compression methods do not cause to loss data [38]. Another method is proposed by Manisha et al., [39] to combine DWT and Discrete Cosine Transform (DCT) in order to lessen storage cost and transmission of image compression. Their method is of three stages; initially, transformation of RGB to luminancechrominance by applying compression process. Secondly, the image is decomposed with the use of DWT and haar transform which uses 2x2 adjacent pixels passes through four filters. Finally, the resultant image is reassembled with the 2D filters. Therefore their method worked better with images that have high compression ratio than the previous method. A novel compression technique was introduced by Delaunay et al., [40]. The technique incorporates tunable complexity rate distortion trade-off. When images size and resolution increase, a more capable technique is required. Earth observation satellites need compression techniques that have a low complexity.

Authors in [41] proposed image compression by redundancy reduction. This could achieve the compression of a basic JPEG by exploiting the individual significant function of MATLAB. The parts, where information loss cannot affect image clarity, compression of lossy technique has been castoff. In order to achieve image compression. Cho et al. [42] presented two compression methods based on Spatial Wavelet Analysis approach.

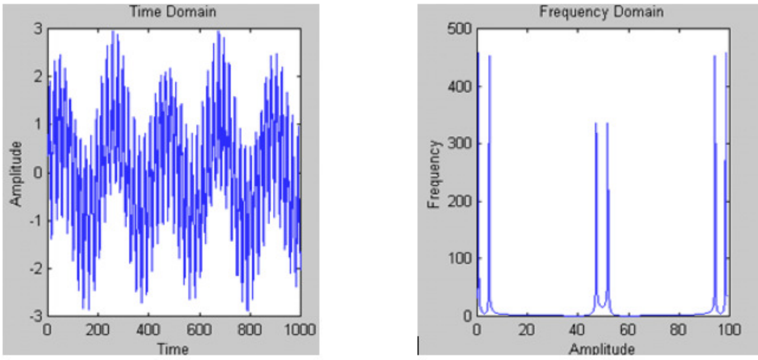
2.1. **Discrete Fourier Transform.** Discrete Fourier transform (DFT) transforms images into frequency domain from spatial domains. Additionally, Fourier transform is equally applicable to filtering, analysis, reconstruction & compression of images as exhibited in fig. 1.

The given eq. (1) and eq. (2) could be used to calculate the DFT.

$$X_k = \sum_{n=0}^{N-1} x_n e^{-j2\pi kn/N} \; k = 1, 2, ..., N \tag{1}$$

$$X_n = \frac{1}{N} \sum_{k=0}^{N-1} x_k e^{j2\pi kn/N} \tag{2}$$

The Fourier transformation is a basic approach to transfer signals from the spatial dimension into the frequency dimension. The FFT is an alternative approach for calculating DFT and produces results at same accuracy as compared to other available approaches



(a) Signal plotted in the time domain **(b) Fourier transform of the signal**

FIGURE 1. Fourier transform of the signal

but at minimum computational cost. The fig. 2 exhibit the DFT process. Initially, DFT is applied to the original image and is divided into two different sets. The first is the real image and the second is the imaginary image as exhibited in fig. 2. Finally, to reconstruct the original image inverse DFT is applied.

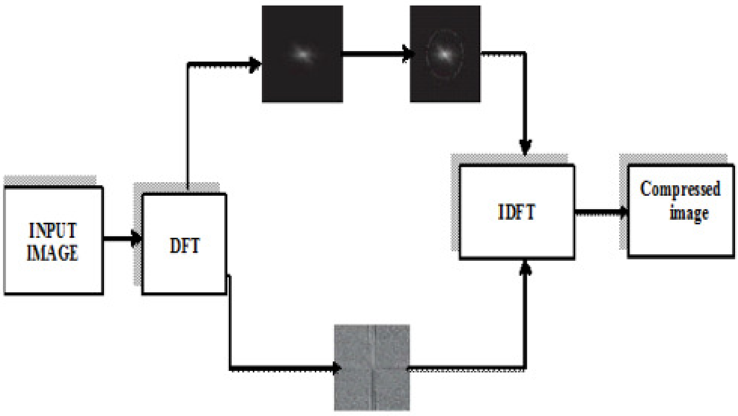


FIGURE 2. Image compression using DFT

2.2. **Discrete Wavelet Transform.** DWTis a multi-resolution decomposition technique that could be used to analyse images and signals. Multi-resolution analysis is performed by means of high-pass filters (wavelets) and low-pass filters (scaling functions). There are two types of pass-filter which are, high pass-filter (wavelets) and low pass-filter (scaling functions). In the first one, wavelets, the signal usually divided into two signals, and it need a high frequency transformation to guarantee the best results.

2.3. **Discrete Cosine Transform.** The original image in the (JPEG) algorithm is segmented into (8×8) or (16×16) blocks. The 2DDCT is calculated for each single block. Then the DCT coefficients are quantized, encoded, and sent. The JPEG receiver deciphers the quantized DCT.coefficients, calculates the 2D-DCT of each block, and then puts the blocks back together in one image. The 2D-DCT is expressed in equation 3:

The 2D-DCT is expressed in eq. (3).

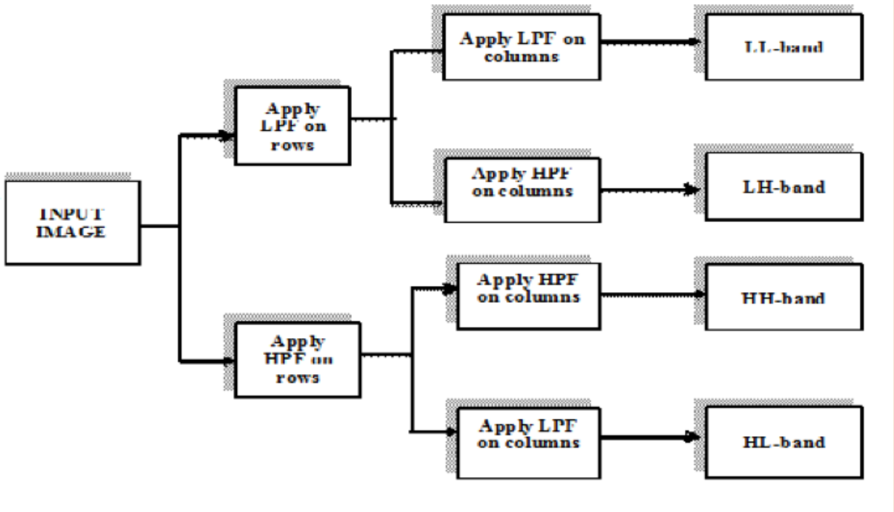


FIGURE 3. Image Compression using DWT

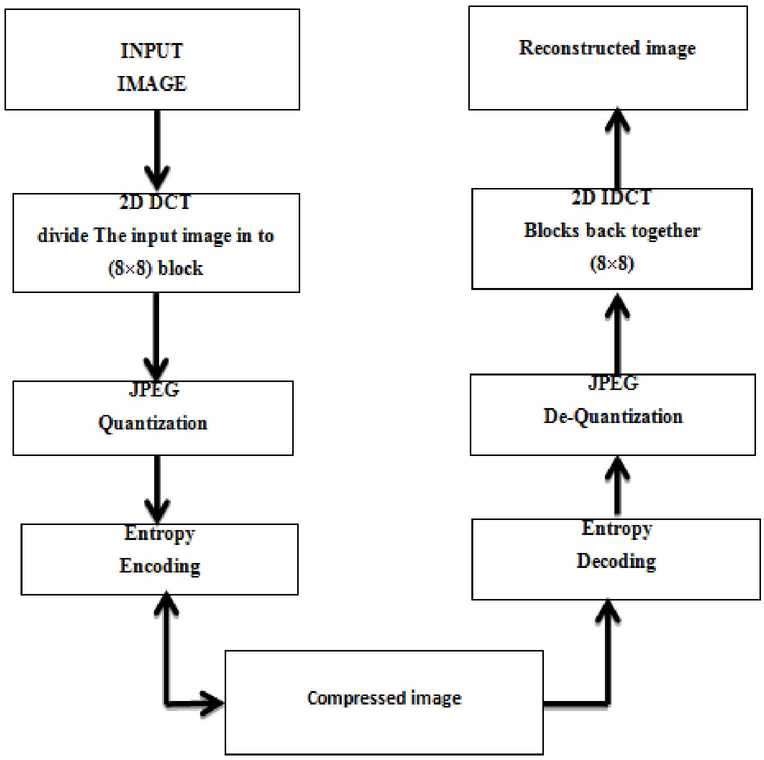


FIGURE 4. 2D-DCT approach

$$B_{pq} = \alpha_p \alpha_q \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} A_{mn} \, Cos \frac{\pi(2m+1)p}{2M} Cos \frac{\pi(2n+1)q}{2N}, 0 \le p \le M-1; 0 \le q \le N-1$$

$$\alpha_p = \begin{cases} 1/\sqrt{M} \\ \sqrt{2/M} \end{cases}, p = 0, 1 \le p \le M-1$$

$$\alpha_p = \begin{cases} 1/\sqrt{N} \\ \sqrt{2/N} \end{cases}, q = 0, 1 \le q \le N-1 \qquad (3)$$

The DCT is an invertible transform whose inverse is given in eq. (4).

$$A_{mn} = \sum_{p=0}^{M-1}\sum_{n=0}^{N-1} \alpha_p \alpha_q B_{pq} Cos \frac{\pi(2m+1)p}{2M} Cos \frac{\pi(2n+1)q}{2N}, 0 \le m \le M-1; 0 \le n \le N-1$$

$$\alpha_p = \begin{cases} 1/\sqrt{M} \\ \sqrt{2/M} \end{cases}, p = 0, 1 \le p \le M-1$$
$$\alpha_p = \begin{cases} 1/\sqrt{N} \\ \sqrt{2/N} \end{cases}, q = 0, 1 \le q \le N-1 \quad (4)$$

The equation of the inverse DCT is presented in eq. (5).

$$\alpha_p \alpha_q = Cos \frac{\pi(2m+1)p}{2M} Cos \frac{\pi(2n+1)q}{2N}, 0 \le p \le M-1; 0 \le q \le N-1 \quad (5)$$

3. **Proposed Fused Image Compression Approach (DFT-DWT-DCT).** Initially, DFT has been applied on the original input image. During the DFT process, a low pass filter and a high pass filter have been used on real and imaginary parts of the DFT. Thus it is better to retain only the real parts of the Fourier converted image. In the next step, DWT has been applied to the Fourier transformed image. During the DWT process, a low pass filter has been applied to the rows and a low pass filer has been applied to the columns in the previous step so that the LL band could be obtained from the DWT process. DCT has been applied to the LL band on the wavelet transformed image. As we have already applied DWT, consequently, it decreases the actual image size to the desired level while retaining the original quality of the image. In DCT, the image is first divided into background and foreground based on edges and then the input image is further subdivided into 8×8 blocks so that 8×8 DCT can be applied to blocks of 8×8. Then the DCT coefficients for every single block can be calculated. During the DCT process, it is also necessary to apply quantization to the DCT coefficients. Thus a quantization table has been used for this purpose. Based on a threshold value selected experimentally, low quantized values can be discarded and the remaining values can be compressed by using an entropy encoder. Thus the proposed method hybridizes three different methods of compression. DWT applies compression by decreasing the size at every level of decomposition and then DCT also performs well for compression of the image. The DCT coefficient contains the maximum frequency to retain the quality of the image. Thus this fused process performs well compared to the original single standalone methods. In the proposed method, compression is applied at three different levels, so it introduces more compression while retaining the quality of the image. The pseudo-code of the suggested method is as such

The architecture of the proposed system is presented in fig. 5.

4. **Results and Discussion.** The two most general techniques that are applied to evaluate the quality of the compressed image and are presented as:

$$PSNR = 10lg\left(\frac{255^2}{MSE}\right) \quad (6)$$

$$MSE = \frac{1}{M \times N}\sum_{i=1}^{M}\sum_{j=1}^{N}(\delta(i,j))^2 \quad (7)$$

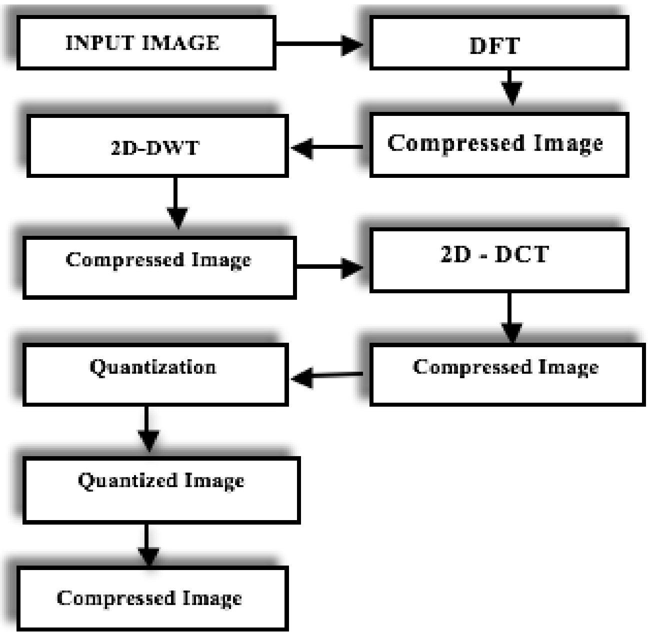


FIGURE 5. Hybrid image compression approach

The proposed image fusion algorithm composed of the following steps
Step 1. Introduce the original image to be compressed
Step 2. Start the DFT processor
Step 3. Start the DWT processor
Step 4. Implement low pass filters on rows
Step 5. Implement low pass filter on columns attained in the just previous step, generating the LL-band
Step 6. Start the DCT processor
Step 7. Divide the input image into background and foreground based on edges
Step 8. Subdivide the input image into 8×8 blocks
Step 9. Find the DCT coefficients for every single block
Step 10. Quantization
Step 11. Quantize the DCT coefficients based on the quantization table
Step 12. Discard the lower quantized values depending on the threshold value selected by the selector
Step 13. Compress the remaining quantized values using the entropy encoder.

FIGURE 6. Decompressed image using DCT algorithm

$$\delta(i,j) = [a(i,j) - \hat{a}(i,j)] \tag{8}$$

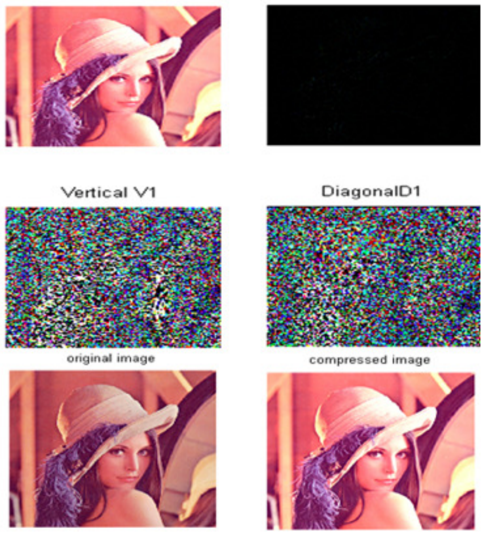


FIGURE 7. Decompressed image using DWT algorithm

FIGURE 8. Decompressed image using DFT algorithm

The (i,j)represent the current pixel position, a(i,j) & $\hat{a}(i,j)$ & are represent the original & compressed images respectively; M, N stand for height & width of the image.

This section presents individual performance of DFT,DWT,DCT, and the fused scheme applications to the input image. fig. 6, fig. 7, fig. 8 and fig. 9 show the decompressed imagesobtained with the use of the DCT, DWT, DFT, and hybrid algorithms, respectively. fig. 10 shows the PSNR and MSE values obtained when the DFT, DWT, DCT, and hybrid algorithms are applied to the image Lena. table 1 lists the compression ratios of the DFT, DWT, DCT, and hybrid algorithms.

To test the effectiveness of the hybrid DFT-DWT-DCT algorithm compared to the standalone DFT, DWT, and DCT algorithms, the proposed approach is implemented in Matlab. The image Lena was applied to validate the effectivenessand productivity of the hybrid DFT-DWT-DCT algorithm and to compare itbythe standalone DFT, DCT, and DWT algorithms.

FIGURE 9. Decompressed image using hybrid algorithm (DFT-DWT-DCT)

The proposed fused image compression is implemented. The hybrid compression technique confers the advantages of all three of the techniques, DFT, DWT, and DCT, but

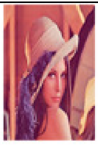
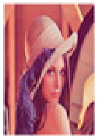
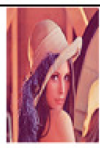
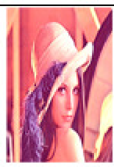
	Image	PSNR value	MSE value
Original image			
DFT algorithm (reconstructed image)		**41.5118**	**4.5909**
DCT algorithm (reconstructed image)		**37.1711**	**12.4730**
DWT algorithm (reconstructed image)		**46.1013**	**1.5957**
Proposed hybrid system (reconstructed image)		**83.6914**	**2.7793**

FIGURE 10. Hybrid Image Compression Results

TABLE 1. Compression Ratios of Various Algorithms

Algorithm name	Original size (kb)	Compressed size (kb)	Compression ratio
DFT	462	36	13:1
DWT	462	45.1	10:1
DCT	462	44.2	10:1
Proposed Approach	462	15.8	29:1

the quality of the image after decompression with DCT, DWT,and DFT alone is not as good as that achieved by the fusion. The hybrid algorithm produces a decompressed image similar to the original image.The performances of the DFT, DWT, DCT, and fused image compression algorithms were analysed by considering the PSNR, MSE, and compression ratio (CR). The PSNR value of fused image compression was 83.6914, which was much better than the PSNR values obtained by DCT,DWT, and DFT. The proposed fused method also achieved a high CR compared with the other algorithms,and the good results obtained show that the proposed fused system performs better in terms of PSNR and MSE values, with a large CR compared to the standalone DFT, DWT, and DCT algorithms.

5. **Conclusion.** This paper has presented a fused approach for image compression at a very low bit rate using a combination of three algorithms: DFT, DWT, and DCT. This work additionally featured with compression quality and preserving good quality of the

reconstructed images at the same time. PSNR and MSE are computed to guarantee the performance of the system. Finally, the compression results thus obtained from proposed approach are compared with the state of the art and it is evaluated that the proposed fusion produced promising results in the state of the art.

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