

Comparative Analysis of Discrete Cosine Transform and Discrete Wavelet Transform on Different Image Files

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Abstract

The process of reducing the quantity of data used in representing certain information content without excessively reducing the quality of the original data is known as compression. It is useful in reducing memory space and time for an information to be transmitted. Data compression can be divided into two classes: lossless and lossy. It is lossless, if no information is lost during compression process. A compression is lossy if the reconstructed image or data is not exactly the same as the original. This paper presents comparative analysis between two lossy compression algorithms – Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT) on images of different sizes with different file formats - JPG, PNG, BMP using Matlab. Important parameters such as compression ratio, compression efficiency, pre-compression and post compression sizes are considered. Experimentally, result shows that DWT performed excellently better than DCT with better compression ratio and higher saving percentage.

Keywords: Discrete Cosine Transform (DCT), Discrete Wavelet Transform (DWT), Compression ratio, Image Compression, Image files.

1. Introduction

The process of reducing the quantity of data used in representing certain information content without excessively reducing the quality of the original data is known as compression. The basic idea behind compression is to reduce the number of bits required to store and/or transmit digital media in a quality and cost-effective manner. Excessive information is removed from the data to reduce its size, hence, the goal of data compression is to represent a source in digital form with as few bits as possible while meeting the minimum requirement of reconstruction of the original (Grgic and Grgic, 2001).

The exponential growth observed in the demand for the use of technology necessitates the need to manage data, especially images, more efficiently. Individuals and some corporate organizations like health industries, retail stores, and Federal Government Agencies depend to a large extent on image processing in their day-to-day activities. For high speed and accuracy, computer applications designed for image processing need to reduce these images to smaller sizes for easy transmission. Hence, the need for image compression cannot be deemphasized (Michael Chui et al., 2012). The compression and decompression techniques are being used for variety of applications like facsimile, printer, document storage and retrieval, teleconferencing, multimedia messaging systems. Therefore, available bandwidth, be it on LAN, WAN, MAN, or Internet needs appropriate compression techniques for reliable communications (Steinmetz, 1994).

Data compression can be divided into two classes: lossless and lossy. It is lossless, if no information is lost during compression process. A compression is lossy if the reconstructed image or data is not exactly the same as the original. In a study carried out by (Jeengar, Omkar, Singh, Yadav and Keshri, 2012), the authors made an assertion that DCT and DWT algorithms have been found in literature as the backbones

of image compression industry, this is because majority of algorithms are based on them. Besides, DCT and DWT based image codecs are widely embraced in image compression due to its overwhelming improved performance and efficiency (Banday and Shah, 2013). Therefore, the merits and reliable performance in the functionalities of both algorithms guided us to make investigative analysis of the two, as this paper presents comparative analysis between two lossy compression algorithms – Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT) on images of different sizes with different file formats - JPG, PNG, BMP on Matlab. This paper is structured as follows: Section 2 presents the related work, section 3 states the methodology adopted for the study, experimental results and discussion are presented in section 4. Finally, section 5 concludes the research work.

2. Related Work

Jasmeet and Sharma (2012) worked on video compression with scalability factor by combining DCT-DWT. In their research, they found out the types of redundancies present in the video frame and how many scenes are correlated in a video for higher compression ratio. Eman and rusulzehwar (2014) examined the color image of size 24-bits/pixel by comparing Fractal Color Image. The compression was done using YIQ and YUV color model. To take the benefit of existing spectral correlation and spatial resolution of human vision system, data of color component are transformed to YIQ color space to enhance more compression and the chromatic components (I.Q) was utilized to increase the compression ratio without making any significant distortion. Rani and Arora (2011) presented a comparative analysis between DCT and DWT techniques of image compression. It compared DCT and DWT by using Mean Square Error (MSE) between the original image and compressed image. MSE value is represented on graph. Their result showed that the quality of DWT is better than DCT while DCT is better than DWT in term of performance.

Grgic and Grgic (2001) proposed new features of wavelet transform in compression of an existing image. The paper discussed how to check the number of wavelet functions implemented in an existing image compression system to highlight the benefit of newly invented transform methods. Tang, Chen, and Song (2012) undertook a study of a hybridized image compression algorithm based on discrete cosine transform (DCT) and discrete wavelet transform (DWT). This algorithm was implemented through the transformation of the color image using DWT in the YCbCr space first, and then DCT in the low frequency, Huffman coding, RLE and arithmetic coding were adopted in the encoded mode. The results show that the algorithm outperforms DCT and DWT, especially, higher in peak signal-to-noise ratio and have better visual quality. Kumar, Huan, & Yung (2017) compared a new lossy and lossless image results using DCT and DWT coding techniques. Their work showed that DCT provides higher compression ratio compared to DWT which has a significantly low compression ratio.

Shaheen, Sheltami, Al-Kharoubi, & Shakshuki (2018) in an attempt to ensure confidentiality and as well reduce image size, proposed the DWT and DCT compression techniques for digital image encryption in wireless sensor networks (WSN). The implementation was performed using MATLAB. Their results showed that the DWT algorithms outperforms the DCT algorithm and also has a minimal end-to-end delay compared to the DWT technique.

2.1 Transformation Based Coding Techniques

To compress images using present day image processing applications, there is a need to exploit correlations between adjacent pixels which is domiciled in transformation coding (Sousa, 2011). According to Salomon (2004), transformation coding constitutes an integral element of contemporary image/video processing applications. Transformation coding relies on the premise that pixels in an image exhibit a certain level of correlation with their adjoining pixels. Consequently, these correlations can be

exploited to predict the value of a pixel from its respective neighbors. The neighboring pixels of the image are projected with highest level of accuracy. After the implementation of transformation coding, image information is observed to be more competent rather than the original image (Banday and Shah, 2013). Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT) are two widely used transformation techniques.

2.2 Discrete Cosine Transform

A transformation is to map the spatial data into transformed coefficient through a mathematical function. The Discrete Cosine Transform (DCT) attempts to decorrelate the image data. Further, each transformation coefficient could be encoded independently with no loss of compression efficiency (Fracastoro, Fosson, and Magli, 2017).

2.3 DCT Performance Evaluation

The decorrelation characteristics of DCT do render a decrease in the entropy of an image, while decrease in the entropy is proportional to the reduction in the average number of bits required for a particular image. The reduction in bits required for particular image in using DCT algorithm is achieved via image transformation into frequency domain with the removal of higher frequency components that are less sensitive to human sight (Banday and Shah, 2013).

2.4 Discrete Cosine Transform Process

A typical image transmission system is outlined in Figure 1. The objective of the source encoder is to exploit the redundancies in image data to provide compression. On the contrary, the channel encoder adds redundancy to the output of the source encoder to enhance the reliability of the transmission. Obviously, both these high-level blocks have contrary objectives (Salomon, 2004).

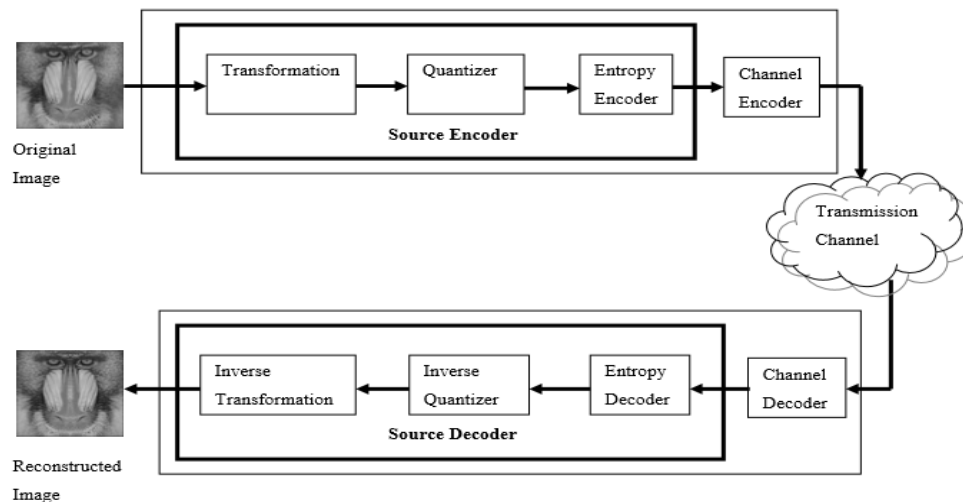


Figure 1: Components of a typical image transmission system (Salomon, 2004)

To achieve better compression, each sub-block in the source encoder exploits some redundancy in the image data. The transformation sub-block decorrelates the image data to reduce or eliminate inter pixel entropy. Being a lossless operation, the inverse transformation outputs an admirable reconstruction of the original image. While considering dimensionality, DCT can be mainly divided into two: one dimensional and two dimensional.

A. One-Dimensional DCT

The most common DCT definition of a 1-D sequence of length L is - If the input sequence has more than L sample points; then it can be divided into sub-sequences of length L where DCT is applied to each independently. While in each such computation, the values of the basis function points would remain unchanged. As a matter of this DCT merit, basic functions can be pre-computed offline and then-after multiplied with the sub-sequences, which subsequently reduces the number of arithmetic operations thereby rendering computation efficiency (Salomon, 2004).

B. Two Dimensional DCT

The 2-D DCT is a direct enhancement of the 1-D. 2-D basis functions can be generated by multiplying the horizontally oriented 1-D basis functions with vertically oriented set of the same functions (Shandilya and Singh, 2015). Again, it can be noted that the basic functions exhibit a progressive increase in frequency both in the vertical and horizontal direction. Hence, this function assumes a constant value and is referred to as the DC coefficient.

C. Image Compression Using DCT

DCT separates images into divisions of dissimilar frequencies where less important frequencies are eliminated through quantization and significant frequencies are used to retrieve the image at decompression process. Compared to other input dependent transforms, DCT has many advantages such as - implemented in single integrated circuit; ability to pack most information in fewest coefficients; minimizes blocking artifact.

D. Steps in Using DCT

Summary of the DCT process as highlighted by Salomon, 2004 is enlisted below:

- Original image is divided into blocks of 4-by-4 or 8 x 8.
- Pixel values of a black and white image range from 0 - 255 but DCT is designed to work on pixel values ranging from -128 to 127.
- Equation (1) is used to calculate DCT matrix.
- DCT is applied to each block by multiplying the modified block with DCT matrix on the left; while transpose of DCT matrix on its right.
- Each block is then compressed through quantization.
- Quantized matrix is then entropy encoded.
- Compressed image is reconstructed through reverse process.
- Inverse DCT is used for decompression

E. Mathematical Implementation of DCT Algorithm

The 2D-DCT algorithm segments the original image into N blocks of size 8x8 pixels. The 2D-DCT can then be observed as a dual processing of two 1D-DCT along individual dimension. The adopted formula of 2D-DCT is as depicted below;

$$D_{xy} = \frac{2}{\sqrt{2K}} C_x C_y \sum_{i=0}^{K-1} \sum_{j=0}^{K-1} P(i, j) \cos \left[\frac{(2i+1)x\pi}{2K} \right] \cos \left[\frac{(2j+1)y\pi}{2K} \right] \quad \dots \quad (1)$$

For $0 \leq x, y \leq K - 1$

While the Inverse 2D-DCT can be expressed as;

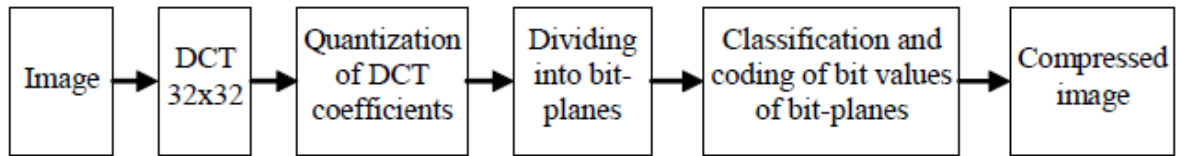
$$P(i, j) = \frac{2}{\sqrt{2K}} \sum_{x=0}^{K-1} \sum_{y=0}^{K-1} C_x C_y D_{xy} \cos \left[\frac{(2i+1)x\pi}{2K} \right] \cos \left[\frac{(2j+1)y\pi}{2K} \right] \dots \quad (2)$$

Where, $P(i,j)$ is an input matrix image $N \times N$, (i, j) mark the coordinates of matrix elements and (x,y) mark the coordinate of coefficients

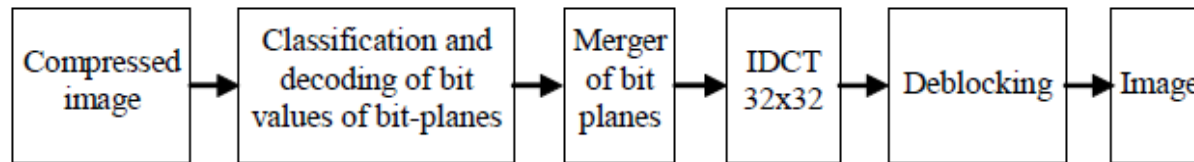
Where C_x and C_y can be expressed as in the following equation;

$$C_x = \begin{cases} \frac{1}{\sqrt{2}}, & x = 0 \\ 1, & x > 0 \end{cases} \dots \quad (3)$$

Block Diagram for 2D DCT



Block diagram for image coding for DCT



Block diagram for image decoding for DCT

2.5 Discrete Wavelet Transform

A wavelet transform decomposes a signal into component wavelets, which aids coefficients of the wavelets to be decimated. As very small wavelets could separate the fine details in a signal; very large wavelets can identify coarse details. In addition, there are many different wavelets to choose from such as – Haar and Daubechies. It is worthy to note that a particular wavelet may generate a more sparse representation of a signal than another, so different kinds of wavelets must be examined to see the most suitable for image or video compression (Malik and Verma, 2012).

DWT is a frequency domain image transform method used to split the information of any digital media into approximated and detailed sub signals respectively. The main objective of DWT technique is to hide data in the form of coefficients as DWT is analyzed on filter bank. In digital image/video processing, two types of filters are extensively used - High and Low pass filters to keep high and low frequency information respectively.

In DWT, signal energy concentrates to specific wavelet coefficients. This characteristic is useful for compressing images and videos. DWT converts the image into a series of wavelets that can be stored more efficiently compared to pixel blocks. It also has rough edges enhancing it to render images better by eliminating the blocky form (Bute, Mandawi, and Sakure, 2013).

A. Haar Wavelet Transform

A Haar wavelet is the simplest type of wavelet. In its discrete form, it is related to a mathematical operation referred to as Haar transform. This Haar transform serves as a prototype for all other wavelet transforms as it equally decomposes a discrete signal into dual sub-signals of half its length. One sub-signal is a running average or trend while the other half is a running difference or fluctuation (Gupta and Choubey, 2015).

B. Daubechies Wavelet Transform

The Daubechies wavelet transforms are similar to Haar wavelet transform by computing the running averages and differences via scalar products with scaling signals and wavelets. The only difference between them is how these scaling signals and wavelets are defined. This wavelet type has balanced frequency responses but non-linear phase responses. Daubechies wavelets use overlapping windows, so the high frequency coefficient spectrum reflects all high frequency changes. Therefore, Daubechies wavelets are useful in compression and noise removal of audio signal processing (Bute, Mandawi, and Sakure, 2013).

C. Mathematical Implementation of DWT Algorithm

Assuming an image with dimension of $V \times U$ pixels, the 2D-DWT algorithm using 2-level will divide the image into 7 sub-images.

$$L_{\phi}(p_o, q, r) = \frac{1}{\sqrt{UV}} \sum_{i=0}^{U-1} \sum_{j=0}^{V-1} P(i, j) \phi_{p_o, q, r}(i, j) \quad \dots \quad (4)$$

Where

$$\phi_{p_o, q, r}(i, j) = 2^{\frac{p_o}{2}} \phi(2^{p_o} i - q, 2^{p_o} j - r) \quad \dots \quad (5)$$

$$L^x \phi(p, q, r) = \frac{1}{\sqrt{UV}} \sum_{i=0}^{U-1} \sum_{j=0}^{V-1} P(i, j) \phi^x_{p, q, r}(i, j) \quad \dots \quad (6)$$

Where

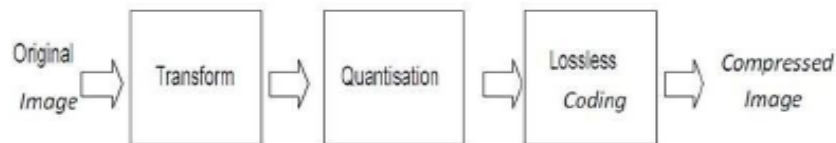
$$\phi^x_{p, q, r}(i, j) = 2^{\frac{p}{2}} \phi^x(2^p i - q, 2^p j - r) \quad \dots \quad (7)$$

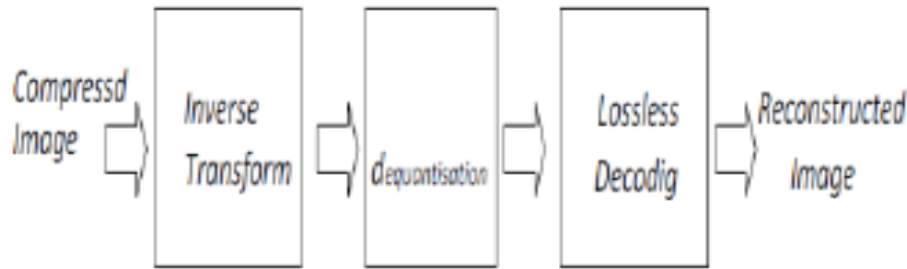
for $x = \{H, V, D\}$

$P(i, j)$ is denoted as the pixel value of the original image. P_o is a starting scale, the coefficients $\phi_{p_o, q, r}(i, j)$ represents an approximation of $P(i, j)$. The $L^x \phi(p, q, r)$ are the coefficients of horizontal, vertical, and diagonal (H, V, D) details respectively for scales $P > P_o$. While the Inverse 2D-DWT can be expressed as;

$$P(i, j) = \frac{1}{\sqrt{UV}} \sum_u \sum_v L_{\phi}(p_o, q, r) \phi_{p_o, q, r}(i, j) + \frac{1}{\sqrt{UV}} \sum_{x=H, V, D} \sum_{P=P_o}^{\infty} \sum_u \sum_v L^x \phi(p, q, r) \phi^x_{p, q, r}(i, j) \quad \dots \quad (8)$$

Block Diagram for 2D DWT





3 Experimental Results and Discussion

In this research, compression methods based on DWT and DCT algorithms have been undertaken using MATLAB. A set of image files such as JPEG, PNG and BMP of different sizes are used to justify the efficiency and effectiveness of both algorithms. The uncompressed image of each format is subjected to three stages of compression; this is to reliably determine the best algorithm for compression. It should be noted that 8 x 8 block division method was adopted for this work.

Table 1: Results Comparing DWT and DCT Image Compression

Name	Original size (KB)	Size after 1 st level DCT Compression (KB)	Size after 1 st level DWT Compression (KB)	1 st level DCT Compression ratio	1 st level DWT Compression ratio	Saving percent age of DCT Compression (%)	Saving percent age of DWT Compression (%)	DCT compression time (seconds)	DWT Compression time (seconds)
Large JPG	1873.92	34	44.7	5.45	41.92	81.6	97.6	19.82	10.91
Small JPG	100	93.2	41.3	1.07	2.42	6.8	58.7	4.98	3.21
Large BMP	2304	769	40.1	2.996	57.46	66.62	98.3	27.3	15.61
Small BMP	147	50.3	40.1	2.92	3.67	65.7	72.7	5.23	7.83
Large PNG	1720.32	657	40.4	2.618	42.58	61.8	97.7	23.02	9.37
Small PNG	240	115	51.4	2.09	4.67	52.08	78.6	11.52	6.03

Table 1 shows the experimental results of both algorithms and it can be deduced that DWT has a better compression ratio and higher saving percentage than DCT for all the image formats chosen as depicted graphically in figures 2 and 3 respectively.

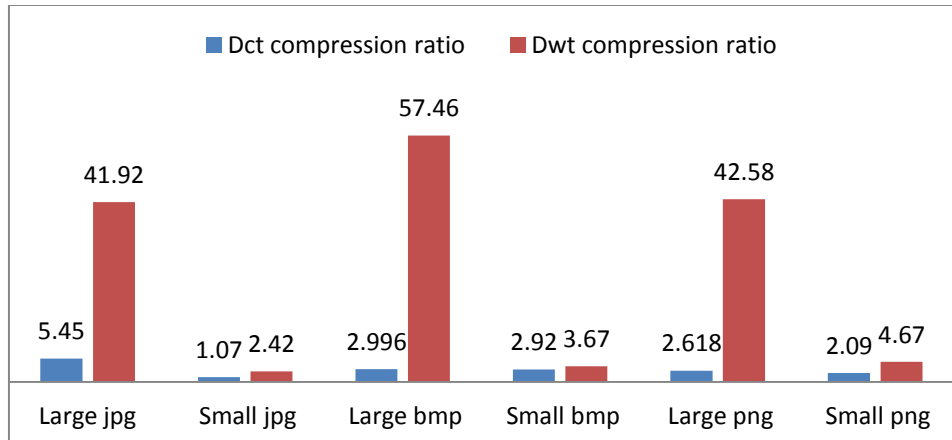


Figure 2: Chart Displaying both DCT and DWT compression ratio

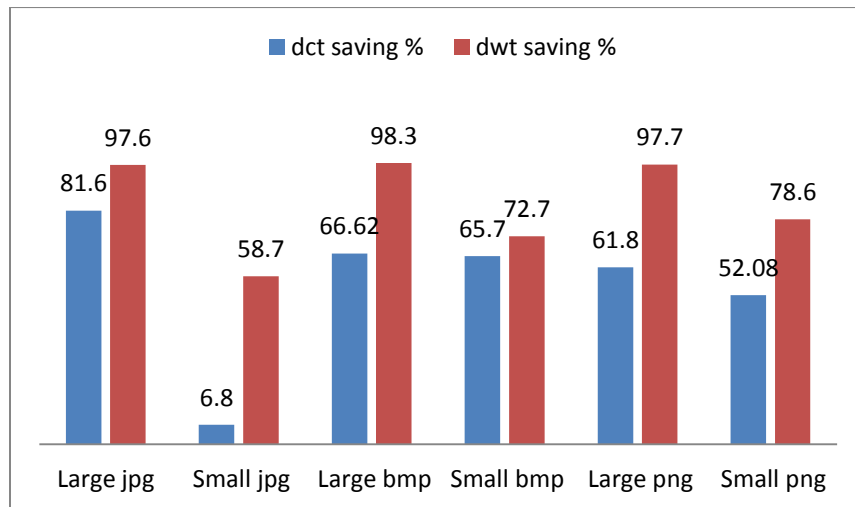


Figure3: Chart Displaying both DCT and DWT saving percentage.



(a)

(b)

Figure 4: Showing results of DWT algorithm on JPG image files
(a) Large files Original Image (b) Large files Compressed image



(a)



(b)



(c)



(d)

Figure 5: Showing results of DWT algorithm on BMP image files
(a) Large files Original Image (b) Large files Compressed image
(c) Smaller files Original Image (d) Smaller files Compressed image



(a)



(b)



Figure 6: Showing results of DWT algorithm on PNG image files
(a) Large files Original Image (b) Large files Compressed image
(c) Smaller files Original Image (d) Smaller files Compressed image

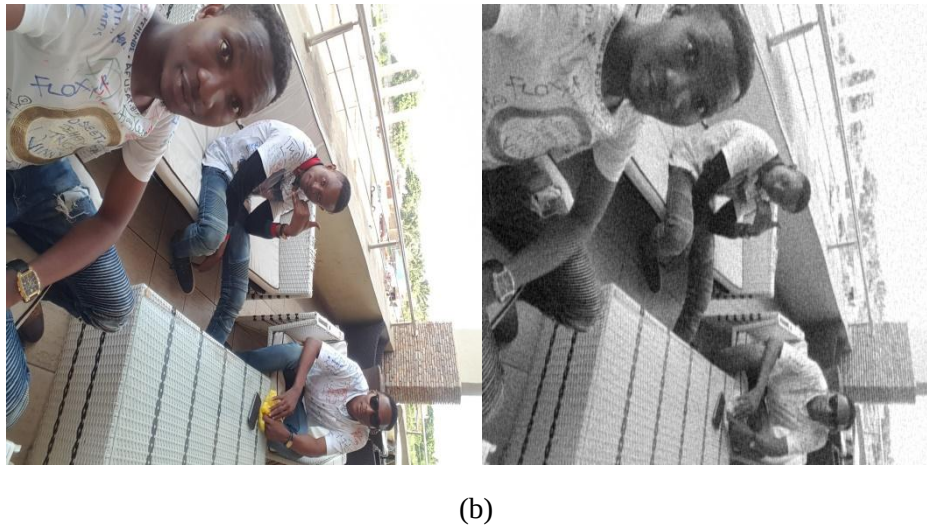
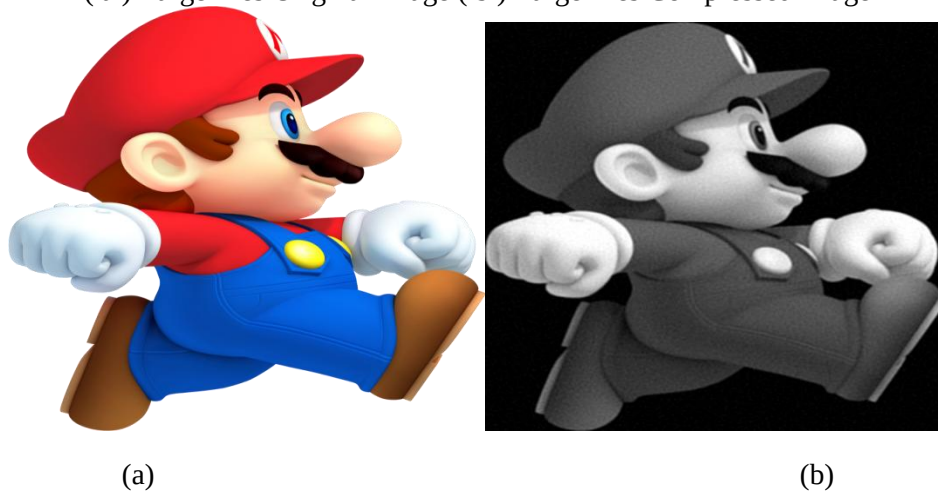


Figure 7: Showing results of DCT algorithm on JPG image files
(a) Large files Original Image (b) Large files Compressed image





(c)



(d)

Figure 8: Showing results of DCT algorithm on PNG image files
(a) Large files Original Image (b) Large files Compressed image
(c) Smaller files Original Image (d) Smaller files Compressed image



(a)



(b)



(c)



(d)

Figure 9: Showing results of DCT algorithm on BMP image files
(a) Large files Original Image (b) Large files Compressed image

(c) Smaller files Original Image (d) Smaller files Compressed image

4. Conclusion

In this paper, a comparative analysis between two compression algorithms; Discrete Cosine Transform (DCT) and Discrete Wavelet Transform (DWT) have been studied and implemented on various image files such as JPG, PNG, BMP, using Matlab. The results show that discrete wavelet transform is better than discrete cosine transform for image compression using the parameters compression ratio and saving percentage.

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