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Efficient Image Compression based on Discrete Wavelet Transform

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ABSTRACT
Image compression is a method that reduces the number of bits used to represent a picture, reducing its size without losing any information. The goal is to reduce bandwidth and memory use without compromising image quality. The proposed method is straightforward and effective, using multiple compression stages, including segmenting the picture into smaller parts and applying discrete wavelet transform (DWT). DWT represents the picture as the sum of wavelet functions at various resolution levels. To maximize compression data rate and provide high-quality reconstructed images, huffman encoding with vector quantize is used. Simulation results show a decent compression ratio and improved SSIM for reconstruction, resulting in high resolution and quality images.

Keywords: DWT, Vector quantization, compression ratio, SSIM

INTRODUCTION

When storing and transmitting images, picture compression is crucial. Compression makes it simple to generate, transfer, and save images of a reasonable size. The signal or data includes some significant information and has some frequent transients.

Consequently, an analysis based on wavelets is required. All that the wavelets are is a brief waveform with a zero average value and a limited duration. The wavelets have a range of -∞ to +∞ when compared to the sine function. The method most often used for picture compression is the discrete wavelet transform [3]. The wavelets in DWT are sampled in a discrete way. A mathematical technique for breaking down pictures or functions is the wavelet. The key characteristic of a wavelet is how it links to other wavelets via translating, shifting, and scaling.

There are 3 types of images are there: binary, grayscale and color images. The binary and grayscale images pixels are represented in a single plane and color images are presented in three plains x, y and z so it is three dimensional. Each pixel has eight bits so that each pixel range is from 0 to 255.

1.1. Image

Image is mainly classified in to three types

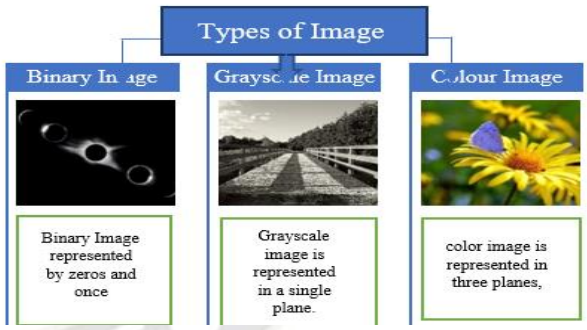

Figure 1: Types of images**Binary Image:** A binary image is one that consists of pixels that can have one of exactly two colors, usually black and white.

- **Grayscale Image:** The value of the gray image is usually represented by **8 bits**, the value range of pixels is 0–255 with a total of 256 grayscale levels
- **Color Image:** Color image is represented in three dimensions x, y and z, each plain represents each primary colors red, green and blue, combination of these three basic colors can create color combinations for a pixel, other colors are called secondary colors.

1.2. DWT Technique

Wavelet transform decomposes a signal into its sub-bands using a series of high-pass and low-pass filters. As noise is generally categorized as a high-frequency component, it is

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easier to separate it from the signal using wavelet transform [10]. The decomposition of frequency content depends on the number of levels of DWT. A signal x(n) can be decomposed into high-pass d_H and lowpass d_L components.

1.3. Vector Quantization

Vector Quantization is a simple technique used for compression in the field of image and video processing. In vector quantization, the coder has two parts: an encoder and a decoder. The encoder assigns each input vector x, to an index i, in the codebook C. The decoder finds the transmitted index i. The distortion is calculated by finding the Euclidian distance between each pixel in x and corresponding pixel in ci and summing over the square of all these distances.

2. LITERATURE SURVEY

Boopathiraja et al [1] proposed A near lossless three-dimensional medical image compression technique using 3D-discrete wavelet transform. in this paper Though it is a transformation-based technique, we desired to achieve better quality because of medical images. The 3D-DWT is used for decomposing and Huffman encoding is used as an encoder. It is evident from results of our proposed method; it saves 0.45 bit-rate averagely for given 3D volumetric images with very low MSE (closest to zero). Threshold approach gives better compression but also maintains the quality of the images.

Aina et al [2] suggested an image compression system based on approximation and wavelet transforms. One benefit of the DWT is that it may achieve a high-quality compression ratio with little information loss. This paper demonstrated how to separate a 2D picture into four sub-band images, including the approximation image and details image, and described the system architecture of the multi-resolution analysis technique to image compression. The MATLAB environment experiment revealed a minimum inaccuracy of 0.0009756. As a result, the two-dimension DWT method is quite effective in producing an image approximation of excellent quality.

Naveenakumara et al [3] proposed an optimized image compression technique based on singular value thresholding in the wavelet domain. they proposed a novelty of improved BTC image compression algorithm on both DWT and SVT for compressed JPEG and PNG images. BTC algorithm is presented. A discrete wavelet transform is applied to the cover image is decomposed into sub-bands of different frequencies at one level. Low frequency sub-band (CA) decomposed using singular value decomposition. Adaptively adjust the low - rank approximation precision threshold as singular value thresholding progresses. Schemes are very simple and do not require complex computations. For future studies.

Hemalatha et al [4] proposed an Image compression using HAAR discrete wavelet transform. The paper aims at developing the effective and more efficient method for image compression using the wavelet transforms. The HAAR DWT plays a significant role in the image compression, Segmentation, JPEG2000 and so on. In this paper higher compression ratio is obtained after three levels of decomposition. The proposed method compresses the image faster. The promising results are obtained by considering the quality of the image as well as the certain image details.

Magar et al [5] developed a hybrid compression method to combine both the lossless and lossy compression for medical image. In this case, the lossless and lossy compression methods are used for ROI and non-ROI image respectively.

Renjith et al [6] proposed Image compression using optimized wavelet filter derived from grey wolf algorithm. In this research, a methodology based on the GWO optimization algorithm for optimizing wavelet filter banks for lossy image compression was presented. The challenge of the optimization process was to find a set of filter coefficients that meets the maximum value of the PSNR and minimizes the error. The challenge was achieved after 1000 iterations of the GWO algorithm. From the results obtained, it is clear that the proposed filter outperforms the three dominant DWT filter banks.

3. BLOCK DIAGRAM

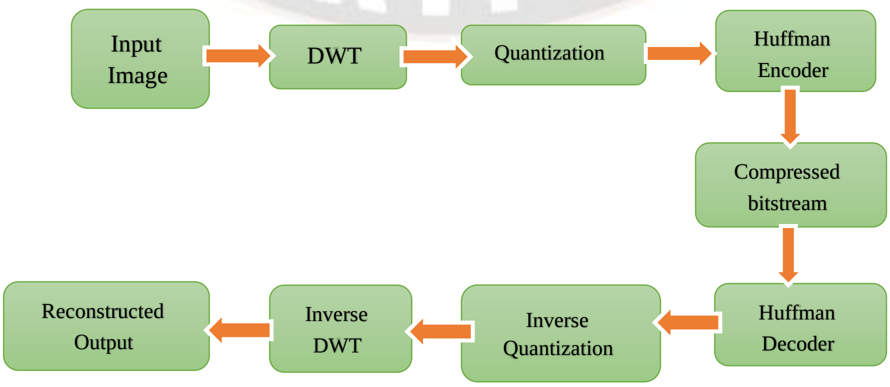

Figure 3: Block diagram of the System

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This project was implemented using the MATLAB approach. This was achieved by using DWT Technique. The above block diagram shows steps Involved in compression process. We compress the image by DWT technique and in other end we reconstruct the image by IDWT method.

3.1. Discrete wavelet transforms

Discrete wavelet transform represents the image as a sum of wavelet function (wave lets) on different resolution levels in addition the quantizer has been used to minimize the compression data rate with high quality reconstructed image, Figure 3 shows the Block diagram for image compression. The ability to do multi-resolution decomposition is a key component of the wavelet transform. The wavelet transform may be used to breakdown a picture and then recreate it with the required resolution. There are two techniques used to extract the frequency range between each other.

- Low Pass Filter (LPF)
- High Pass Filter (HPF)

This filter pair (LPF, HPF) is called Analysis Filter pair. The filtering is done on Rows & Columns.

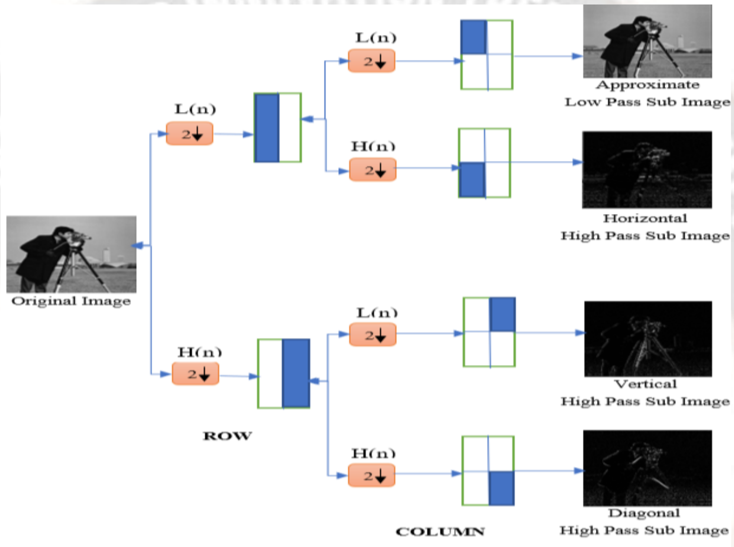

Figure 4: Discrete Wavelet Transform Row and Column Procedure

Rows (Procedure):

- ➢ The low pass filter is applied for each row of data, and then we get low frequency components of the row. As the LPF is a half band filter, the output data consists of frequencies only in the first half of the original frequency range. By Shannon's Sampling Theorem, they can be sub sampled by two the output data contains only half the original number of samples.
- ➢ The high pass filter is applied for the same row of data, and now the high pass components are separated, and placed by the side of the low pass components.
- ➢ This is done for all rows.

Column (Procedure):

- ➢ The low pass filter and high pass filter is applied for each column of data. As a result, we get four bands of data, each labelled as LL (low-low), HL (high-low), LH (low-high) and HH (high-high).

➢ The LL band can be decomposed once again in the same manner, thereby producing even more sub bands. This can be done up to any level, thereby resulting in a pyramidal decomposition as shown above the LL band at the highest level can be said as most important, and the other bands are of lesser importance. The degree of importance decreases from the top of the pyramid to bottom.

3.2. Vector Quantization

A lossy compression method used in voice and picture coding is vector quantisation. In scalar quantisation, we select a scalar value from a limited set of potential values to represent a sample. To represent an input vector of samples in vector quantisation, a vector is chosen from a finite set of potential vectors. The fundamental process of vector quantisation is encoding a random vector as a binary codeword. You may think of each input vector as a point in an n-dimensional space. The vector quantizer is defined as dividing this space into a collection of nonoverlapping n-dimensional sections. By comparing it to a codebook made up of a collection of saved reference vectors known as code-vectors, the vector is encoded. The optimality criteria require the quantisation region to contain all vectors in a quantisation area that are closer to their code-vector than any other, and the code-vector to be the average of all these vectors.

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3.3. Huffman Encoding

The Huffman encoding method is the most effective coding technique when compared to other encoding techniques. It is often used to generate the fewest codes for representation. Huffman coding is determined by the speed at which a data pixel is connected to images. The idea is to encrypt data that happens more often with fewer bits. The bit length of the compressed picture is shortened by using the Huffman coding technique. Using the Huffman coding technique, identify the codes that are not used as prefixes to any other codes. The length of the code depends on how often it is that a character will occur. The most probable character has the least code length in order to provide the best outcome [12]. The original data is accurately retrieved by the decoder using the encoded code. The compressed image goes through a reverse decompression process in order to retrieve the image. It is necessary to decode the Huffman-encoded data before extracting the coefficients. After that, the codebook and set of indexes are sent to the VQ decoder so it can correctly reconstruct the data. Currently, the decoder looks for the code word in the codebook using the indices in order to recreate the wavelet coefficients at the block level. After rebuilding the co-efficient from each sub-band at different levels, an inverted DWT is used to extract the image. The size of the original and the reproduced picture is the same.

4. FLOW CHART

➢ **Encoding:**

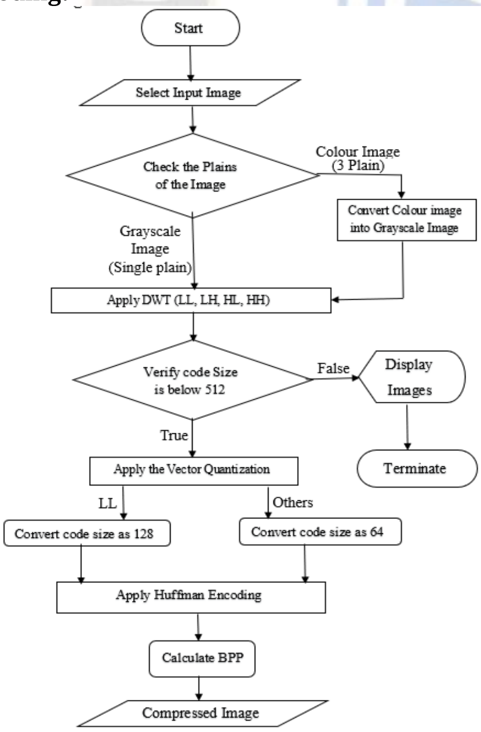


Figure 5(a): Encoding

➢ **Decoding:**

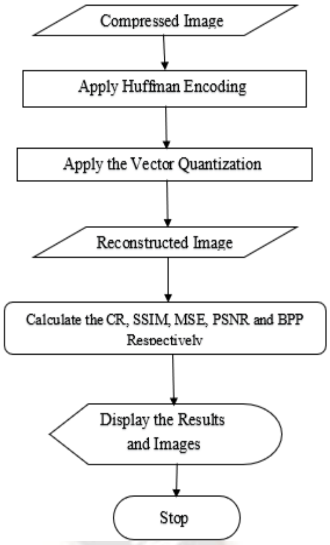


Figure 5(b): Decoding

5. RESULT ANALYSIS

Cameraman

(a) Original Image (b) Sub-Image (c) Compressed Image

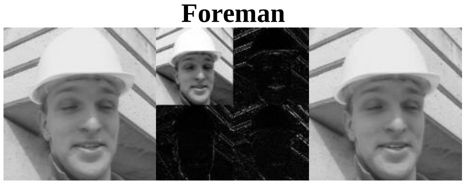
Home

(a) Original Image (b) Sub-Image (c) Compressed Image

Fence

(a) Original Image (b) Sub-Image (c) Compressed Image

Foreman



(a) Original Image (b) Sub-Image (c) Compressed Image

Starfish

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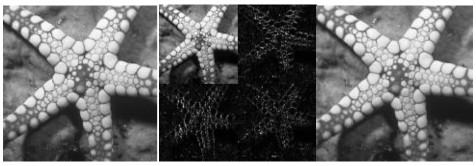
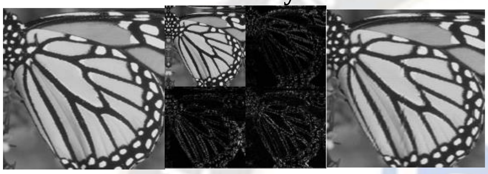


(a) Original Image (b) Sub-Image (c) Compressed Image

Leaves

(a) Original Image (b) Sub-Image (c) Compressed Image

Butterfly



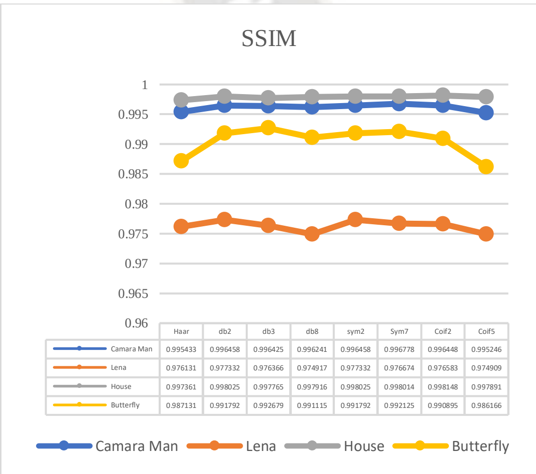
(a) Original Image (b) Sub-Image (c) Compressed Image

Lena

(a) Original Image (b) Sub-Image (c) Compressed Image

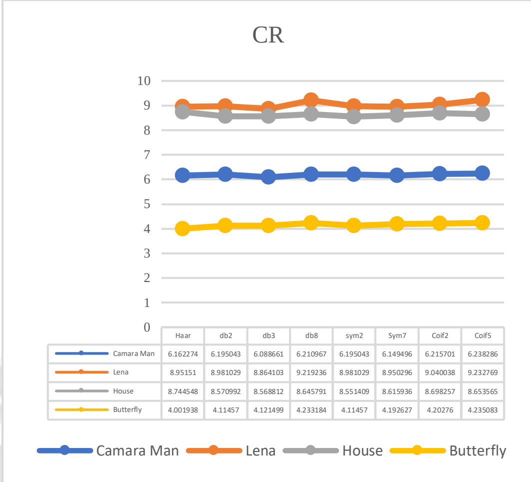
Figure 6: single stage DWT applied to different Images

5.1. Different Wavelets Results



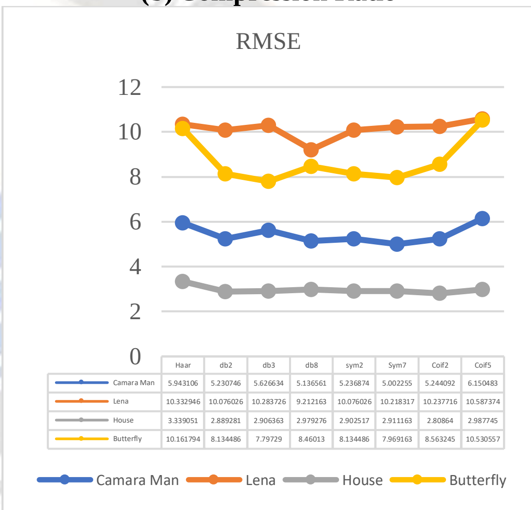
	Haar	db2	db3	db8	sym2	Sym7	Coif2	Coif5
Camara Man	0.995433	0.996458	0.996425	0.996241	0.996458	0.996778	0.996448	0.995246
Lena	0.976131	0.977332	0.976366	0.974917	0.977332	0.976674	0.976583	0.974909
House	0.997361	0.998025	0.997765	0.997916	0.998025	0.998014	0.998148	0.997891
Butterfly	0.987131	0.991792	0.992679	0.991115	0.991792	0.992125	0.990895	0.986166

(a) Structure Similarity Index Measurement



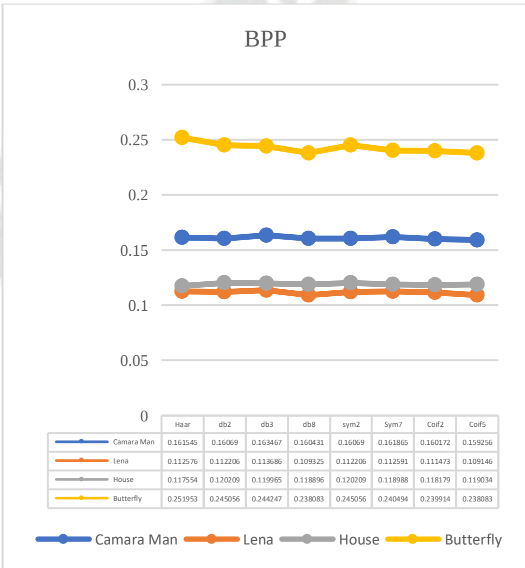
	Haar	db2	db3	db8	sym2	Sym7	Coif2	Coif5
Camara Man	6.162274	6.195043	6.088661	6.210967	6.195043	6.149496	6.215701	6.238286
Lena	8.95151	8.981029	8.864103	9.219236	8.981029	8.950296	9.040038	9.232769
House	8.744548	8.570992	8.568812	8.645791	8.551409	8.615936	8.698257	8.653565
Butterfly	4.001938	4.11457	4.121499	4.233184	4.11457	4.192627	4.20276	4.235083

(b) Compression Ratio



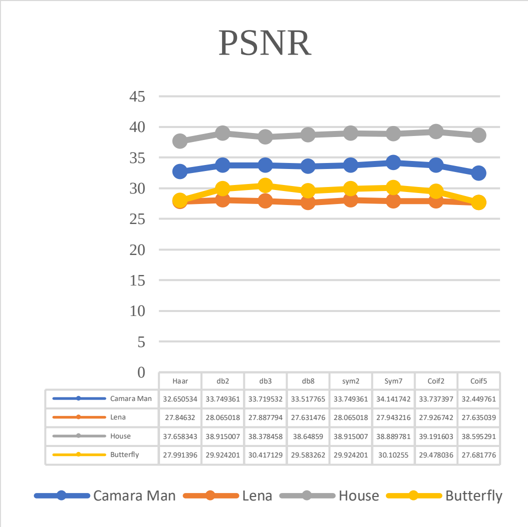
	Haar	db2	db3	db8	sym2	Sym7	Coif2	Coif5
Camara Man	5.943106	5.230746	5.626634	5.136561	5.236874	5.002255	5.244092	6.150483
Lena	10.332946	10.076026	10.283726	9.212163	10.076026	10.218317	10.237716	10.587374
House	3.339051	2.889281	2.906363	2.979276	2.902517	2.911163	2.80864	2.987745
Butterfly	10.161794	8.134486	7.79729	8.46013	8.134486	7.969163	8.563245	10.530557

© Root Mean Square Error



	Haar	db2	db3	db8	sym2	Sym7	Coif2	Coif5
Camara Man	0.161545	0.16069	0.163467	0.160431	0.16069	0.161865	0.160172	0.159256
Lena	0.112576	0.112206	0.113686	0.109325	0.112206	0.112591	0.111473	0.109146
House	0.117554	0.120209	0.119965	0.118896	0.120209	0.118988	0.118179	0.119034
Butterfly	0.251953	0.245056	0.244247	0.238083	0.245056	0.240494	0.239914	0.238083

(d) Bits Per Pixel



	Haar	db2	db3	db8	sym2	Sym7	Coif2	Coif5
Camara Man	32.650534	33.749361	33.719532	33.517765	33.749361	34.141742	33.737397	32.449761
Lena	27.84632	28.065018	27.887794	27.631476	28.065018	27.943216	27.926742	27.635039
House	37.658343	38.915007	38.378458	38.64859	38.915007	38.889781	39.191603	38.595291
Butterfly	27.991396	29.924201	30.417129	29.583262	29.924201	30.10255	29.478036	27.681776

(e) Peak Signal to Novice Ratio

Figure 7: Figure of different wavelets for different input Images

Performance Parameters:

Compression Ratio: CR is the ratio between the original file size of the image and the compressed file size.

$$\textbf{CR} = \frac{\text{Original image size}}{\text{Compressed image size}}$$

Bits Per Pixel: BPP denote that the number of bits required for storing a single sample. The formula for BPP is given as below.

$$\textbf{BPP} = \frac{\text{Compressed Image size}}{\text{Total number of pixels}}$$

Peak Signal to Noise Ratio: PSNR is the ratio between the peak value and the error on images. PSNR formula is given as,

$$\textbf{PSNR} = 10 \log 10 \left(\frac{\text{MAXI\^{}2}}{\text{MSE}}\right)$$

Where MAXI is maximum fluctuation in an image, and MSE is the mean square error between the images.

Mean-Square Error: The mean-square error (MSE) and the peak signal-to-noise ratio (PSNR) are used to compare image compression quality. The MSE represents the cumulative squared error between the compressed and the original image, whereas PSNR represents a measure of the peak error. The lower the value of MSE, the lower the error

$$\textbf{MSE} = \frac{1}{\text{m.n}} \sum_i \sum_j (X(i,j) - Y(i,j))^2$$

Where n is the total number of pixels, Y (i, j) indicates the pixel value in the compressed image and X (i, j) expresses a pixel value in the original image

The Structural Similarity index: SSIM is a method for measuring the similarity between two images. The SSIM index can be viewed as a quality measure of one of the images being compared, provided the other image is regarded as of perfect quality.

$$\textbf{SSIM} = \frac{((2.\mu x.\mu y + e) * (2 * \text{covariance} + e))}{((\mu x)2 + (\mu y)2) + e) * (\text{variance\_x} + \text{var\_y} + e))}$$

CONCLUSION

The paper aims at developing the effective and more efficient method for image compression using the wavelet transforms, an Image compression technique using DWT in MATLAB has been design and implement. The Image compression technique used Huffman coding, quantization and DWT technology in the design; this is because they are easy to use and fast in compression and reconstruction of image. A low cost and highly quality image compression technique that can used in medical, satellite, military communication, Tele conferencing systems, as well as a user-friendly device was designed. We can save the time and storage space.

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