

Efficient Image Compression Technique using JPEG2000 with Adaptive Threshold

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Abstract

Image compression is a technique to reduce the size of image which is helpful for transforms. Due to the limited communication bandwidth we have to need optimum compressed image with good visual quality. Although the JPEG2000 compression technique is ideal for image processing as it uses DWT (Discrete Wavelet Transform). But in this paper we proposed fast and efficient image compression scheme using JPEG2000 technique with adaptive subband threshold. Actually we used subband adaptive threshold in decomposition section which gives us more compression ratio and good visual quality other than existing compression techniques. The subband adaptive threshold that concentrates on denoising each subband (except lowest coefficient subbands) by minimizing insignificant coefficients and adapt with modified coefficients which are significant and more responsible for image reconstruction. Finally we use embedded block coding with optimized truncation (EBCOT) entropy coder that gives three different passes which gives more compressed image. This proposed method is compared to other existing approach and give superior result that satisfy the human visual quality and also these resulting compressed images are evaluated by the performance parameter PSNR.

Keywords: Image, JPEG2000, DWT, Adaptive Threshold, and EBCOT.

1. INTRODUCTION

A digital image is an array of pixels, where each pixel represents the intensity or brightness of the image at its respective location. Each pixel is a signed or unsigned integer and can be represented using bits. A gray scale image has one value per pixel location while a color image has three values per pixel location. Imaging is a very basic way for humans to convey information to one another and also express the emotion of a human voice. But it is very difficult to store and transmit the data if the size of the image is large. In this case image compression is performed. The only objective of image compression technique is to reduce the redundancy of the image data in order to store or transmit data in an efficient manner. Compression technique reduces the file size and allows to store more images in a given amount of disk or memory space [1][2]. Generally two types of image compression technique are used for compressing the image those are lossy compression and lossless compression [3]. In case of lossy compression technique, the original signal cannot be exactly reconstructed from the compressed data, because of much of the detail in an image is discarded. Lossy compression provide high compression ratio but degrade the image quality. In a lossless compression, compressed data is used to recreate an exact replica of the original with no content loss to the compression process. Lossless compression provides good visualization but does not provide sufficient high compression ratio. That's why we need the compression algorithm which will provide high compression ratio and also provide good visualization [4]. Generally for image compression, JPEG and JPEG2000 and some other compression algorithm are used. JPEG uses Discrete

Cosine Transform (DCT) which give high compression ratio but it gives lowest quality image. On the other side the JPEG2000 uses Discrete Wavelet Transform (DWT) that is based on sub-band technologies [5][6]. Comparatively it gives high compression ratio with good image quality. This paper described a modified technique based on JPEG200 that analyze the image as perform discrete wavelet transform in different level with adaptive threshold. This proposed technique provides better result than other existing techniques by improving compression ratio and image quality.

This paper is organized as follows: Section 2 discuss about the JPEG2000compression. In section 3 the proposed JPEG 2000 based compression with adaptive threshold is elaborated, while the experimental analysis and results are explained in section 4 followed by conclusion in section 5.

2. ABOUT JPEG2000

JPEG2000 is an international standard compression technology and it is a powerful new tool that provides power capabilities for designers and users of networked imaging applications. It is a compression standard enabling both lossless and lossy storage. This technique improves the quality and compression ratios, but also requires more computational power to process. JPEG2000 is a new wavelet based compression methodology [6] that provides many benefits over DCT compression method which was used in the JPEG format. The architecture of the basic JPEG2000 encoder and decoder are shown in Fig.1.

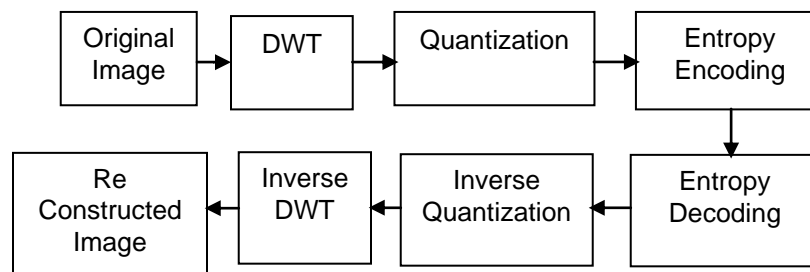


FIGURE 1: Basic Architecture of JPEG2000 Encoder and Decoder.

In JPEG2000, a DWT is used which transform the image into a series of wavelets that can be stored more efficiently than pixel blocks. After transformation, all coefficients are quantized using quantization. The quantized coefficients are entropy coded, and sent as output code stream (bit stream).

3. PROPOSED ARCHITECTURE

Digital Images are compressed through usage of various standards based techniques and algorithms. The lossless compression techniques are used in places where the quality and accuracy of image is of extreme important. Although the lossless compression not give high compression ratio, so we have given emphasize on compression to get the high ratio with respect to human visual quality and measured the quality by using the performance parameter like as PSNR. Finally to achieve a higher compression rate for lossless-compressed gray images, we propose a JPEG2000 based compression scheme incorporated with an adaptive threshold. The proposed method consists of four stages: Discrete Wavelet Transform, Adaptive Threshold, Quantization, and embedded block coding with optimized truncation coding (EBCOT) as shown in Fig.2 and briefly described as follows:

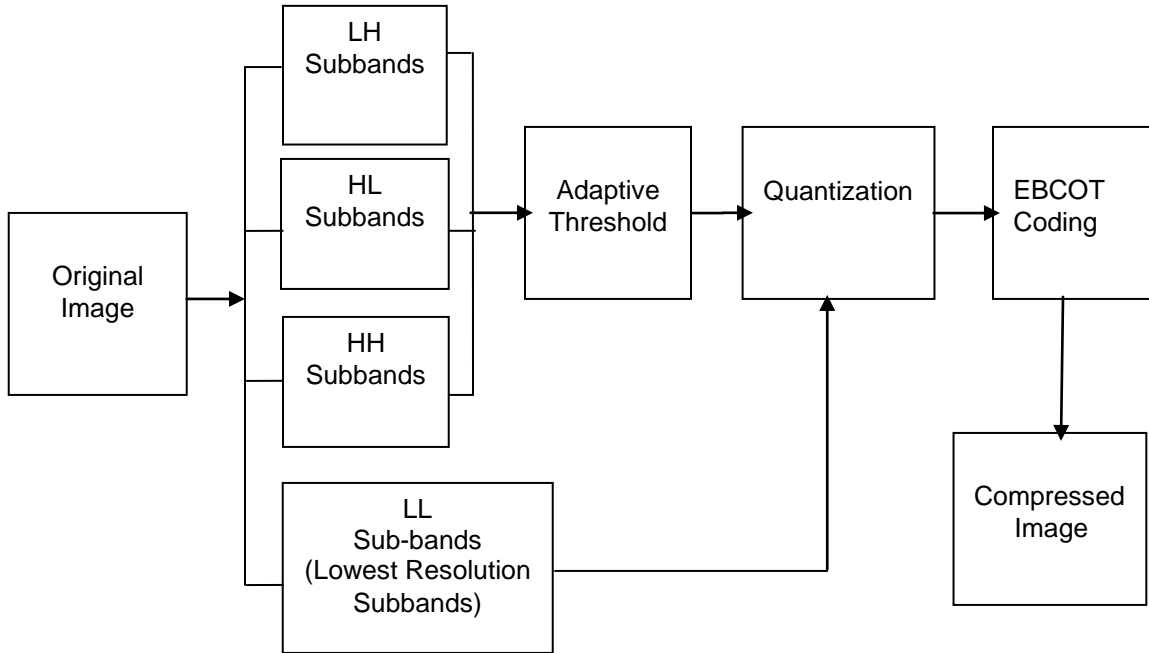


FIGURE 2: Proposed JPEG2000 Based Block Scheme with Adaptive Threshold.

3.1 Discrete Wavelet Transform

DWT can be used to reduce the image size without losing much of the resolution. The DWT [7] [8] apply it to a whole original image and provide a different level of decomposition with coefficients block of image and the block of transformed coefficients are classified into types HH, HL, LH, and LL. These types are described as Diagonal, horizontal, vertical, and image approximation. The DWT applied on an image is depicted by Fig.3.1

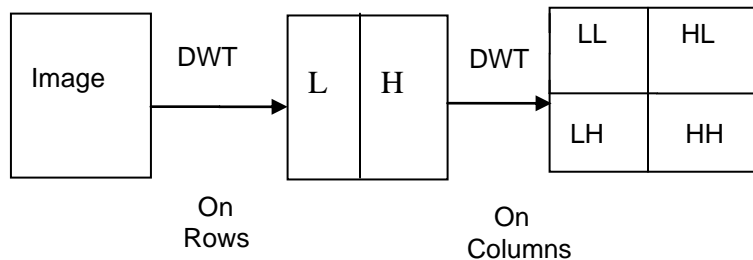


FIGURE 3.1: DWT Applied on Image.

Suppose we have taken an original image and then we apply low pass filter and high pass filter on the rows. Since we are applying the wavelet transform in both the dimensions, so we first apply on the rows and then columns [9] [10]. Whenever we apply low pass filter on rows to preserve the lowest discrete time frequency that is horizontal approximation and apply high pass filter to preserve the highest discrete time frequency that is horizontal detail. After getting the horizontal approximation we again apply low pass filter on column to get the approximate image (LL) and apply high pass filter on column to get the vertical details (LH). Similarly After getting the horizontal detail we again apply low pass filter on column to get the horizontal details (HL) and apply high pass filter on column to get the diagonal details (HH). The 2D discrete wavelet transform can be implemented with below figure.3.2:

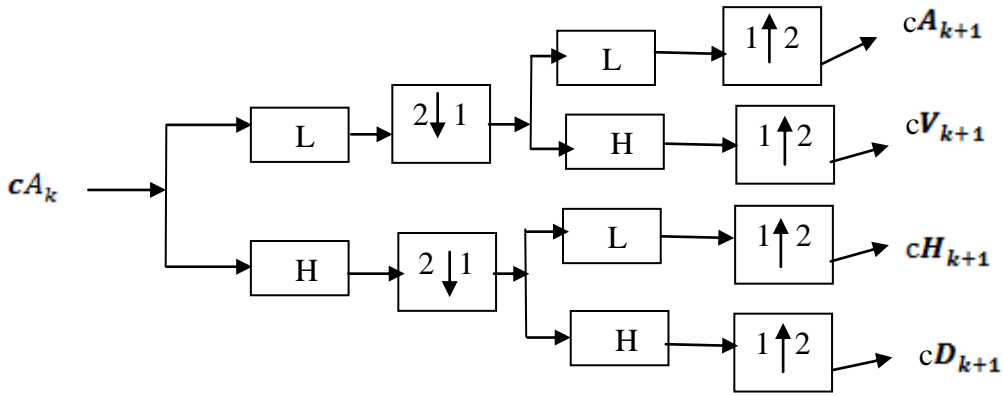


FIGURE 3.2: 2D DWT Implementation.

The low-pass and high-pass decomposition filters are represented as L and H, respectively. Applying and both in horizontal and vertical directions to the original image $I(i, j)$, and next, recursively to the resulting gradually coefficients, we can obtain the following decomposition coefficients.

$$cA_{k+1} = \sum_{m=-\infty}^{+\infty} \sum_{n=-\infty}^{+\infty} L(2i - m)L(2j - n)A_{m,n} \quad (1.1)$$

$$cV_{k+1} = \sum_{m=-\infty}^{+\infty} \sum_{n=-\infty}^{+\infty} L(2i - m)H(2j - n)A_{m,n} \quad (1.2)$$

$$cH_{k+1} = \sum_{m=-\infty}^{+\infty} \sum_{n=-\infty}^{+\infty} H(2i - m)L(2j - n)A_{m,n} \quad (1.3)$$

$$cD_{k+1} = \sum_{m=-\infty}^{+\infty} \sum_{n=-\infty}^{+\infty} H(2i - m)H(2j - n)A_{m,n} \quad (1.4)$$

The sub-bands are labeled by using following:

(1.1). LL (cA_{k+1}) is the approximation image that indicate low-frequency component (LL) resulting from low-pass filtering in the vertical and horizontal directions.

(1.2). HL (cV_{k+1}) represents the vertical details that results from vertical low-pass filtering and horizontal high-pass filtering.

(1.3). LH (cH_{k+1}) represents the horizontal details that results from horizontal low-pass filtering and vertical high-pass filtering.

(1.4). HH (cD_{k+1}) represents the diagonal details that results from high-pass filtering in both directions.

3.2 Adaptive Threshold

This section describes the method for computing the threshold value T , which is adaptive to different sub-bands characteristics [11] [12] for each subbands (except loest resolution subband). After getting the all sub-band coefficients we just applied adaptive threshold into all sub-band coefficients except lowest resolution that's mean image approximation part. Actually this part carry significant bit for image reconstruction with noise free. Actually highest resolution parts that are diagonal, vertical and horizontal carry high value with noise. In that part an adaptive threshold is applied and adapts all coefficients with modified value. The new threshold is calculated by the following equation:

$$T_{new} = \sigma\sqrt{2\log M}$$

Where M is the number of pixels in the image and σ is the noise variance that is defined as:

$$\sigma = \frac{\text{median}|(Y_{i,j})|}{0.6745}$$

Here $Y(i, j) \in \text{HH}$ sub-band coefficients those are obtained by applying the wavelet transform to the image.

Now we adapt all sub-bands (except lowest resolution subband) using following equation:

$$\hat{Y}(i,j) = \begin{cases} (Y(i,j) - |T_{new}|), & |Y(i,j)| > T_{new} \\ 0, & |Y(i,j)| \leq T_{new} \end{cases}$$

Where $\hat{Y}(i,j)$ is estimated sub-band

3.3 Quantization

The quantization process is calculated by the following equation:

$$Q(i,j) = \text{sign}(\hat{Y}(i,j)) \left\lceil \frac{|\hat{Y}(i,j)|}{\Delta n} \right\rceil$$

Where $Q(i, j)$ is the quantized result at position (i, j) and $\hat{Y}(i,j)$ represent the original DWT coefficient at position (i, j) and Δn stands for the interval width for quantization

3.4 EBCOT Coder

After quantization, each sub-band is divided into rectangular blocks, called code-blocks. These code-blocks are encoded independently. The code-block is decomposed into planes and they are encoded from the most significant plane to the least significant bit-plane sequentially.

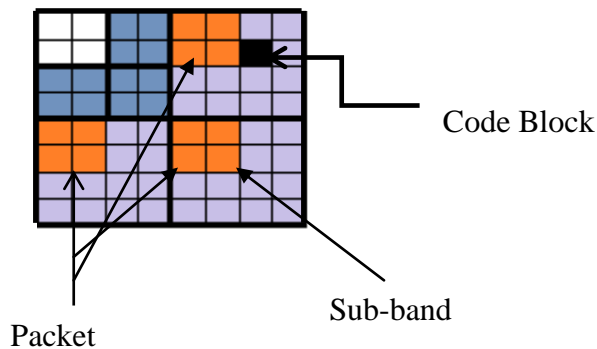


FIGURE 3.3: Partitioning Into Code Block.

The embedded block coding with optimized truncation (EBCOT) encodes each plane in three coding passes [13]. The three coding passes in the order in which they are performed on each plane are significant propagation pass, magnitude refinement pass, and cleanup pass. All three types of coding passes scan the samples of a code block in the same order.

The three passes are described below:

a) Significance propagation pass: During the significance propagation pass, a bit is coded if its location is not significant, but at least one of its eight connects neighbors is significant.

b) Magnitude refinement pass: During this pass, all bits that became significant in a previous biplane are coded. The magnitude refinement pass includes the bits from coefficients that are already significant.

c) Clean-up pass : The clean-up pass is the final pass in which all bits not encoded during the previous passes are encoded (i.e., coefficients that are insignificant and had the context value of

zero during the significance propagation pass). The very first pass in a new code block is always a clean-up pass.

After every small block receives three coding passes in every bit-plane, the bit-stream will be generated. These bit-streams need to be reassembled to form the fine bit-stream. The second coding stage is for packaging the bit-streams from the first coding stage into data units called packets. The resulting packets are then assembled into the final bit stream.

4. EXPERIMENTAL RESULT AND ANALYSIS

In this paper, an efficient image compression technique based on JPEG2000 is studied. An image is taken to justify the effectiveness of the algorithm. The resulting compressed image is compared to different existing techniques like JPEG. Also the proposed technique is compared to existing JPEG2000 that gives high compression ratio and it gives visually better image quality which is evaluated by the performance parameter Peak Signal Noise Ratio (PSNR). The three 512 x 512 gray scale images considered for analysis that are "Lena image", "Barbara image" and "Baboon image".

The Peak Signal to noise Ratio PSNR is estimated by the following equation:

$$PSNR = 10 \log_{10} \frac{(255)^2}{MSE}$$

Where MSE refers to the mean squared error between the original image and the reconstructed image and MSE can be calculated by the following equation:

$$MSE = \left[\frac{\sum_{i=0}^{M-1} \sum_{j=0}^{N-1} (X(i,j) - Y(i,j))^2}{M * N} \right]$$

Where X means original Image and Y means processed Image. MxN is size of Image and x means row and y means columns.

By using the above formulae in the proposed technique the following parameters are calculated for the Lena image, Barbara image and Baboon image and resulting compressed images that are given in the following below:



FIGURE 4.1: Original Images (Lena Image, Barbara Image and Baboon Image).



FIGURE 4.2: Compressed Images using JPEG (Lena Image, Barbara Image and Baboon Image).



FIGURE 4.3: Compressed Images using JPEG2000 (Lena Image, Barbara Image and Baboon Image).



FIGURE 4.4: Compressed images using Proposed method (Lena image, Barbara image and Baboon image).

The experimental results with the proposed compression method compared to different existing techniques have been arranged in the Table 1, Table 2 and Table 3 that are given in the following below:

Compression Techniques	File sizes	Compression Ratio	PSNR
Original Image (Lena.bmp)	257.00 KB	----	----
JPEG	18.48 KB	13.90 : 1	24.42
JPEG2000	8.03 KB	31.99 : 1	40.53
Proposed Method	7.07 KB	36.35 : 1	40.97

TABLE 1.1: Comparison between Proposed method and other Compression Methods for the “Lena image”.

Compression Techniques	File sizes	Compression Ratio	PSNR
Original Image (Barbara.bmp)	257.00 KB	----	----
JPEG	19.89 KB	12.92 : 1	16.42
JPEG2000	9.18 KB	27.97 : 1	35.03
Proposed Method	8.07 KB	31.81 : 1	36.02

TABLE 1.2: Comparison between Proposed method and other Compression Methods for the “Barbara image”.

Compression Techniques	File sizes	Compression Ratio	PSNR
Original Image (Baboon.bmp)	257.00 KB	----	----
JPEG	23.92 KB	10.74 : 1	14.68
JPEG2000	10.71 KB	23.99 : 1	27.37
Proposed Method	9.42 KB	27.26 : 1	27.89

TABLE 1.3: Comparison between Proposed method and other Compression Methods for the “Baboon image”.

From the comparison table we see that the experimental results demonstrate that the proposed compression technique gives better performance compared to other compression techniques.

5. CONCLUSION

In this paper, we improve the JPEG 2000 image compression technique by adding adaptive threshold. The effectiveness of the proposed technique has been justified using a set of still images. From the experimental results it is clear that the proposed method perform better compression than JPEG and JPEG2000 compression techniques. The experimental result also shows that the proposed method produce the output which are more cleaner and smoother and at the same time kept significant details, resulting in a clearer and appealing vision.

6. REFERENCES

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