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Combining of Spatial and Frequency Domain Transformation With The Effect of Using and Non-Using Adaptive Quantization for Image Compression

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Abstract

Usage of image has been increasing and used in many applications. Image compression plays vital role in saving storage space and saving time while sending images over network. One important point of delivering digital image is time. In this paper we concentrated on the speed of packet sending with reasonable quality. The aim of this paper is to reduce image size with reasonable quality. By getting advantage from image transformation in both scope spatial domain and frequency domain. Splitting the image into 4 blocks in the case of spatial domain and applying Standard Haar wavelet transformation in the case of frequency domain was the main factor for approaching the aim of this paper which was reduce image size and increase speed of delivering digital image. After huge tests in the case of frequency domain in all subbands(LL,HL,LH,HH) we made a decision for which subband contains high information and which subband contains poor information. Depending of these factors we could send less than one-eighth of the size of the original image to the destination and getting the reconstructed image with the acceptable quality as a result of this paper.

Keywords: *-Haar Wavelet Transformation; Adaptive Quantization; Spatial Domain; Frequency Domain; PSNR ; Mean Square Error; Compression Ratio; Variable Encoding RLE; Image Quality*

1. Introduction

The image compression highly used in all applications like medical imaging, satellite imaging, etc. The image compression helps to reduce the size of the image, so that the compressed image could be sent over the computer network from one place to another in short amount of time. Also, the compressed image helps to store more number of images on the storage device [1,2].

Image compression plays a critical role in telemetric applications. It is desired that either single image or sequences of images be transmitted over computer networks at large distances so that they could be used for a multitude of purposes. For instance, it is necessary that medical images can be transmitted so as to be reliable, improved and fast medical diagnosis performed by many centers could be facilitated. To this end, image compression is an important research issue [3].

Images contain large amounts of information that requires much storage space, large transmission bandwidths and long transmission times. Therefore it is advantageous to compress the image by storing only the essential information needed to reconstruct the image. An image can be thought of as a matrix of pixel (or intensity) values. In order to compress the image, redundancies must be exploited, for example, areas where there is little or no change between pixel values. Therefore images having large areas of uniform color will have large redundancies, and conversely images that have frequent and large changes in color will be less redundant and harder to compress.

Wavelet analysis can be used to divide the information of an image into approximation and detail subsignals. The approximation subsignal shows the general trend of pixel values, and three detail subsignals show the vertical, horizontal and diagonal details in the image.

The aims behind the adaptive quantization are to quantize the retained coefficients after transformation step according to the quantity of information existed in each subbands and to obtain a large sequence of zeros especially in (HL, LH and HH) bands [4].

In general, Figure 1 shows all steps of the work in this paper as a diagram. Steps are including:

1- Convert the original image in the case of spatial domain by taking average mean of neighboring and getting (original image2).
2- Splitting the (original image2) into 4 blocks in the case of spatial domain.
3- Putting zero value for all blocks except the top-left block which remain as its.
4- Applying Standard Haar wavelet (2^{nd} level) on the remained block (Top-left).
5- Putting zero value for eight blocks out of 16 blocks.
6- Applying adaptive quantization on 4 blocks out of 8 remained blocks.
7- Apply variable run length encoding to find compression ratio.

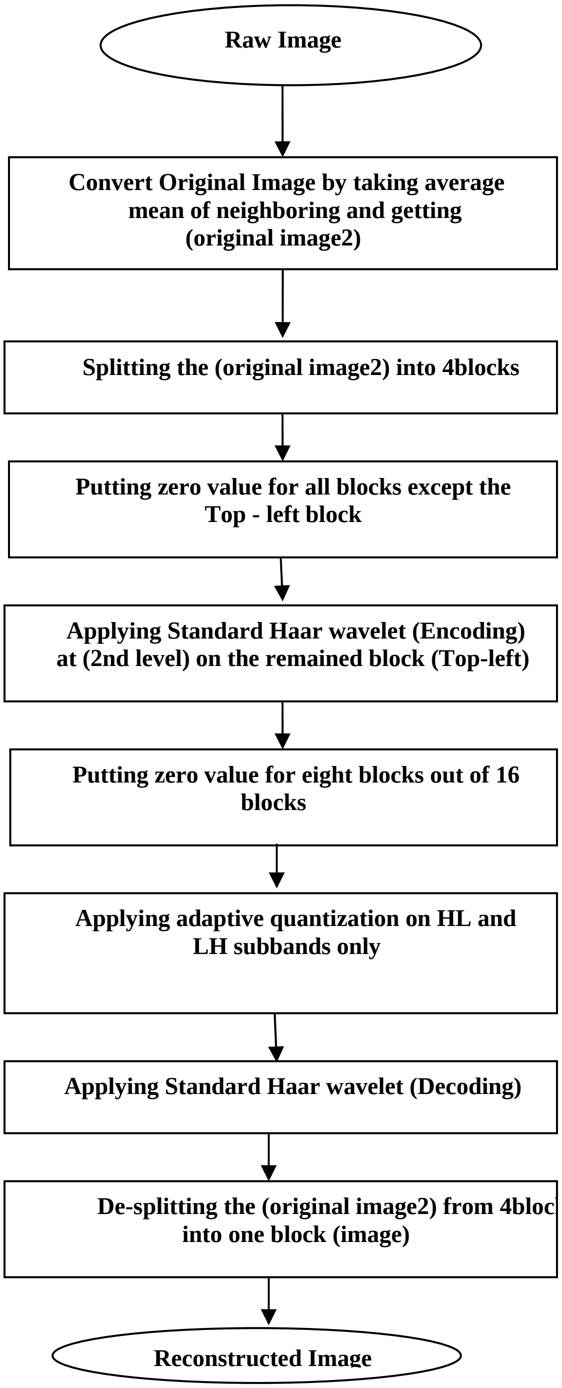


Figure 1. Diagram of paper's procedure

2. Methods and Materials Procedure

2.1. Spatial Domain Conversion

The term spatial domain refers to the image plane itself, and approaches in this domain are based on direct manipulation of pixels in an image. The spatial domain is aggregate of pixels composing an image. Spatial domain methods are procedures that operate directly on these pixels. Spatial domain processes will be denoted by the expression

$$g(x,y)=T\left[f(x,y)\right]$$

Where $f(x,y)$ is the input image, $g(x,y)$ is the processed image, and T is an operation on f ,defined over some neighborhood of (x,y) [5].

In this paper the spatial domain conversion done in two steps which are discussed in 2.1.1., 2.1.2 and 2.1.3.

2.1.1. Average Mean of Neighboring

It is one of the methods that operate on the pixels directly. By taking the average value of 4 neighbor pixels and put this average value for each one of these 4 neighbor pixels. After applying average mean on original image (shown in Figure.2) the image result shown in Figure.3.

Figure 2. Original image

Figure 3. Image after applying average mean

2.1.2 Splitting image(Figure 3) into 4 Blocks

It is another method that operates on the spatial domain. In this step, image splits into 4 blocks with equal sizes (shown in Figure.4). The aim of splitting is to work only on one block and ignore other three blocks in order to reduce size.

Figure 4. Splitting image(in Figure.3) into 4 blocks

2.1.3. Putting zero value

By putting zero values to three blocks except top-left block as third step in the spatial domain (shown in Figure.5) as ignoring these three blocks.

Figure 5. Putting zero to three blocks

2.2 Frequency Domain Conversion

Frequency domain conversion includes:

2.2.1. Applying Standard Haar wavelet (Encoding)

By applying standard Haar wavelet at 2nd level on the remained block (Top-left block of Figure.5), the image transfer from its spatial domain to frequency domain. At the 1st level the frequency domain includes 4 subbands (LL,HL,LH,HH) then by applying wavelet again on each subband, the frequency domain includes 16 subbands (LL of LL1, HL-LL1, LH-LL1, HH-LL1,LL-HL1,HL-HL1,LH-HL1,HH-HL1,LL-LH1,HL-LH1,LH-LH1,HH-LH1,LL-HH1,HL-HH1,LH-HH1,HH-HH1) as shown in Figure 6.

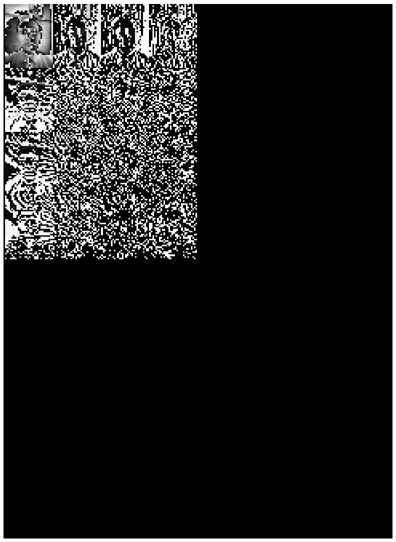


Figure 6. After applying Standard Haar Wavelet (2^{nd} level)

2.2.2. Putting zero to the subbands

By putting zero to the subbands that contains poor information. After a lot of tests, show that eight subbands contain poor information. For example HL subband contains vertical information,then by applying wavelet again the LH of HL contains poor information because there is no horizontal information in the HL subband. According to these tests , we put zero value to eight subbans out of 16 subbands as shown in Figure 7.

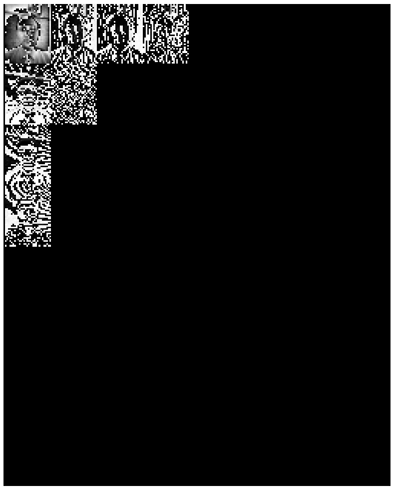


Figure 7. putting zero values to 8 subbands

2.2.3. Applying Adaptive Quantization

Normally, Wavelet data is erratic and very small and large numbers are obtained from applying the DWT. However, much of this data can be discarded with minimal loss to the final image. We apply Quantization to wavelet data to achieve this. Quantization is a very important part of compression when dealing with wavelets [6]. In these tests, a universal scalar step size is used for quantization of all the packets. The amount of compression went up significantly when more quantization was applied. This is due to the greater amount of zeros after quantization (zeros are encoded very efficiently).

In this paper, adaptive quantization applied on HL and LH subbands only in the previous image, because all subbands of LL in the 2nd level (LL of LL, HL of LL, LH of LL, HH of LL) contain important information, by applying adaptive quantization the most important information will be lost. As you see, in the previous image all subbands of HH (LL of HH,HL of HH,LH of HH, HH of HH) ignored (set zero for all subbands), so it doesn't need to apply quantization on it. The remained subbands that need to apply quantization are four subbands out of 8 subbands which are,(LL of HL,HL of HL,LLof LH,LH of LH) as shown in Figure.8 with quantization value 20 and α = 0.5 (while the values of alpha (α) parameter was varied between 0→1).

Adaptive algorithm for forward quantization is as follows:

$$Q\_f = round\left(\frac{Y(x,y)}{Q\_LL}\right)$$

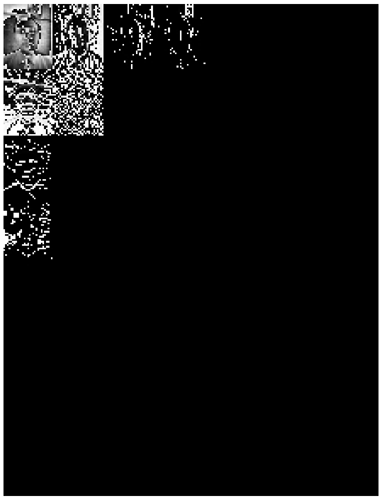


Figure 8. Applying adaptive quantization on ,(LLof HL,HL of HL,LL of LH,LH of LH) subbands with quantization value 20 for each subband and α **=0.5**

2.2.4. Applying Standard Haar wavelet (Decoding)

After applying standard Haar wavelet decoding on previous image(in Figure 8), the reconstructed image shown in Figure 9.

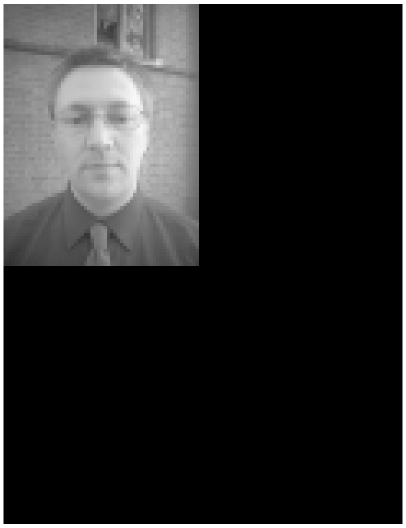


Figure 9. Reconstructed image

Then by de-converting the reconstructed image (in Figure 9) from one block to 4 blocks the image becomes:

Figure 10. De-converting from one block to 4 blocks

Then by de-splitting the image(in Figure 10) from 4 blocks into one image. The final reconstructed image is:

Figure 11. Final reconstructed image (one-sixteenth of the original image size) (16 subbands out of 64 subbands)

3. Experimental study and discussion of the results

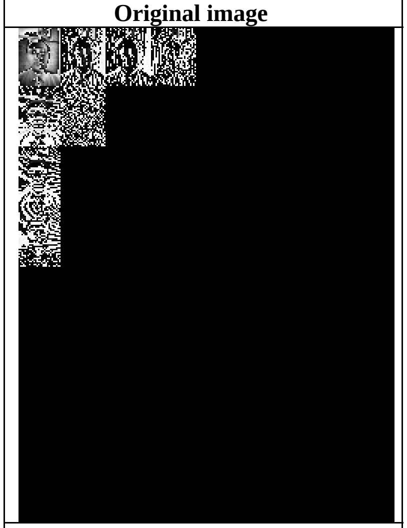
The major effort in this work has been set to the direction of defining the significant and non significant of image compression.

The proposed processing scheme tested on several different images (as shown in table 1) but in this paper displayed only one image as an instance by two steps (as shown in Figure.12,13). The first without quantization and the second with quantization. Depending on the image quality measurements (PSNR , MSE) for the first one (without quantization) PSNR and MSE are reasonable which means that the image quality is reasonable, that means by sending 16 packets (subbands) out of 64 packets to the destination, the image quality is very reasonable. For the second step, (with quantization =20, alpha=0.5) the PSNR and MSE are acceptable, that means the image quality is acceptable, that means by sending less than 16 packets out of 64 to the destination, the image quality is acceptable. After that, according to the compression ratio, which supports the previous discussion, we can see the effect of quantization on the speed of delivery and image quality. The compression ratio (C.R.) is the amount of original data divided by the amount of compressed data. The least amount of data needed to represent all of the image information is constrained by the amount of information contained in the values encoded.

$$C.R. = \frac{\text{amount of original data}}{\text{amount of compressed data}}$$

The amount of information contained in the values or symbols encoded can be quantitatively measured [7].

Original image

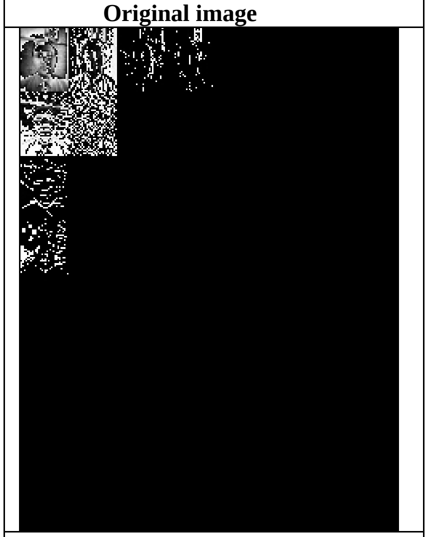


16 subbands out of 64

Reconstructed image
PSNR= 29 MSE= 9 C.R=1.95

Figure 12. without quantization

Original image



16 subbands out of 64 with quantization= 20 , alpha= 0. 5

Reconstructed image
PSNR= 24 MSE= 31 C.R= 2.77

Figure 13. with quantization

Table 1: RESULTS OF C.R, MSE AND PSNR BETWEEN ORIGINAL IMAGE AND RECONSTRUCTED IMAGE WITHOUT AND WITH QUANTIZATION

Original image	**Without quantization**			**With quantization**		
	MSE	**PSNR**	**C.R**	**MSE**	**PSNR**	**C.R**
Image1	19	21	1.89	58	17	2.5
Image2	9	26	2.09	34	20	2.86
Image3	5	29	2	16	24	2.74
Image4	30	32	1.97	71	27	2.67
Image5	8	39	2.03	33	32	2.68

4. Conclusions

The present experiment reveals that the proposed procedure achieves better compression ratio with using adaptive quantization than without using. The tested results show that the quality of reconstructed image is better in the case of without using adaptive quantization which was PSNR= 29 dB. This is contrast of the case of using adaptive quantization which was PSNR = 24 dB, but the C.R was better. In this paper, Standard Haar wavelet used for the second level because in Standard all subbands are equal in size, as we treat each subband as a packet so the Standard wavelet was useful for this issue.

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