The Effect on Compressed Image Quality Using Standard Deviation-Based Thresholding Algorithm

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***Abstract*—In recent decades, digital images have become increasingly important. With many modern applications use image graphics extensively, it tends to burden both the storage and transmission process. Despite the technological advances in storage and transmission, the demands placed on storage and bandwidth capacities still exceeded its availability. Compression is one of the solutions to this problem but elimination some of the data degrades the image quality. Therefore, the Standard Deviation-Based Thresholding Algorithm is proposed to estimate an accurate threshold value for a better-compressed image quality. The threshold value is obtained by examining the wavelet coefficients dispersion on each wavelet subband using Standard Deviation concept. The resulting compressed image shows a better image quality with PSNR value above 40dB.**

***Index Terms*—Compression; Image Quality; Standard Deviation; Thresholding.**

I. Introduction

In recent decades, with the rapid development in the multimedia world, digital images have become important. For instance, a 24-bit pixel can specify up to $2^{24} \approx 16.78$ million colour, resulting in a 786 432 bytes image size just for a 512 x 512 image resolution. With many modern applications employing image graphics extensively, it tends to burden the storage as well as the transmission process. Therefore, there is a need to reduce the image size and compression is one of the more promising techniques [1]

Compression is a process of reducing the amount of redundant data while maintaining the good quality of the reproduced image [2], [3]. Compression is essential particularly to reduce storage space, transmission time, bandwidth utilization and to enable rapid browsing and retrieval of images from the database [4].

Recently, there is a growing interest among researchers focusing on compression of various types of images and data. There are many examples of existing research on standard grey scale images [5]–[8], medical images [9]–[11] and ECG signals [12], [13]. Amongst various compression algorithms, transform-based compression is one of the promising algorithms [14].

II. Literature Review

There are a huge number of approaches proposed in the literature, mainly focusing on developing an algorithm that able to compact an image as much as possible to a smaller size. From the reading, it is identified that wavelet is the most prominent tool used in compression as proved by a number of algorithms suggested [11], [15]–[17].

Eliminating unwanted information is a major aspect in compression. This can be achieved by performing thresholding process [18]–[22] as well as quantization [14], [23]–[26]. Digital images generally contain significant amounts of spatial and spectral redundancy. Spatial redundancy is due to the correlation between neighbouring pixel values, while spectral redundancy is due to the correlation between different colour planes. In image processing, the original domain is referred to as a spatial domain, whereas the result depends on transform domain [27].

Thresholding is a process of shrinking the small absolute coefficients value while retaining the large absolute coefficient value [28]. The small absolute coefficients value are usually caused by noise while large absolute coefficients value are triggered by significant features. Generally, most of the wavelet coefficients are concentrated at near zero with a small value. But the tendency differs at each particular subband as it associated to its resolution [29].

Threshold value estimation is very crucial in image compression. If the threshold value is set too small, it will adopt noise into data and compression ratio is not decreased. Whereas, if the threshold value is set too high, it will increase the compression ratio, but the value of the important coefficient will be screened out, leading to a destructive data condition [30].

One of the interesting threshold work can be found in [31]. In this work, the psychovisual experiment is used to detect the threshold value on image subband. The experiment was done manually by recursively search the highest possible threshold value where Human Visual System (HVS) cannot detect any changes or degradation of image quality. Then, each image coefficient is compared to this value, where coefficients with a higher value than the psychovisual threshold value will be retained while the rest will be discarded. Although this algorithm can suggest a good threshold value below visual noticeable change, it suffers from time-consuming because of manual testing.

In research done by [29], a unique thresholding algorithm was proposed by measuring the energy in decomposition subband. The energy of subband was obtained by calculating the dominant coefficient that contributes maximum energy. This dominant coefficient value is then set as the threshold value and it is eliminated. The algorithm presents a satisfactory compression ratio but it only tested on texture image which had a largely similar characteristic.

III. PROPOSED ALGORITHM

Generally, the wavelet coefficients are concentrated at near zero value. By a proper estimation of these near-zero value, the elimination of these coefficients can be done. Here, more space can save up, thus increasing the compression ratio. In this research, a concept of estimating the near-zero coefficients using Standard Deviation concept is introduced and later this value is used for thresholding purposes.

Firstly, the wavelet coefficients were obtained by transforming the original image using Discrete Wavelet Transform (DWT). Discrete Wavelet Transform is used as transformation tool as it can provide energy compaction besides the coefficients are grouped based on its characteristic or resolution.

The original image will pass the analysis filter to split the original image to several spectral components. The image also passes a low pass filter for approximation coefficients outputs. Then, it will pass through the high pass filter to enhance the details [32].

In analysis filter, some points need to be eliminated. This operation is called downsampling. The process is done to maximize the amount of necessary detail. This process will give a smoothing effect to the image. This analysis was done repeatedly until it reaches the desired scale.

As a result, wavelet coefficients in four subbands are generated. The approximate coefficients are placed in approximate subband (low-resolution approximate image) while the detail coefficients are placed in horizontal subband (intensity variation along the column, horizontal edge), vertical subband (intensity variation along the row, vertical edge) and a diagonal subband (intensity variation along diagonal) [33].

Next, the wavelet coefficients obtained from the DWT process are used to provide dispersion information of subband. It contains various value starting from 0 till x_{max} where x_{max} is the maximum coefficients in the respective subband [34].

Here, the Standard Deviation-Based Thresholding Algorithm is proposed by introducing an improved thresholding algorithm that can estimate the suitable threshold value by measuring the dispersion trend on wavelet coefficients in each detail subband using standard deviation concept. The Standard Deviation-Based Thresholding Algorithm can signify and eliminate as much as possible near-zero valued coefficients to increase compression ratio without harming the significant coefficients.

For each detail subbands (Horizontal, Vertical and Diagonal subband), the individual threshold value λ, is calculated and then applied to detail coefficients value respectively. The retained coefficients are only the significant valued coefficients that sufficient enough in reconstructing back a good quality image. The threshold value for diagonal subband is represented by λ_D. While λ_V and λ_H are representing the threshold value for vertical and horizontal subbands respectively.

For diagonal subband, to obtain the threshold value, the mean value for the diagonal subband, M_D is calculated first. Then the threshold value, λ_D is calculated based on standard deviation value of wavelet coefficient at diagonal subband. This value is then being used to estimate the near-zero coefficient value for an efficient coefficient elimination.

$$M_D = \frac{1}{n}\sum_{i=1}^{n}\omega_{\varphi}^{D}(j_0,k_1,k_2) \tag{1}$$

$$\lambda_D = (\frac{1}{n}\sum_{i=1}^{n}(\omega_{\varphi}^{D}(j_0,k_1,k_2) - M_D)^2)^{\frac{1}{2}} \tag{2}$$

By using the calculated threshold value for diagonal subband λ_D, as obtained in Equation (2), the thresholding process is then performed. If the decoder found that $\omega_{\varphi}^{D}(j_0,k_1,k_2)$ are larger than the calculated λ_D, then it knows that the coefficient is significant and the coefficient is retained. Otherwise, if $\omega_{\varphi}^{D}(j_0,k_1,k_2)$ is lesser than λ_D, it is classified as near-zero coefficients and these coefficients are discarded. So, the new remaining diagonal detail coefficients can be obtained by expressing the thresholding equation as in Equation (3).

$$\omega_{\varphi}^{D}(j_0,k_1,k_2)_{new} = \begin{cases} \omega_{\varphi}^{D}(j_0,k_1,k_2), & |\omega_{\varphi}^{D}(j_0,k_1,k_2)| \geq \lambda_D \\ 0, & |\omega_{\varphi}^{D}(j_0,k_1,k_2)| < \lambda_D \end{cases} \tag{3}$$

This thresholding process remains until the test was done to all single wavelet coefficients in the diagonal subband. The Equation (3) will effectively zero down the near-zero coefficients without harming the significant coefficients since the significant one was kept unchanged. The same process also is done to Horizontal and Vertical subbands concurrently.

IV. RESULTS AND ANALYSIS

Using these equations, the standard deviation value as stated in Table 1 were generated. From Table 1, it can be seen that the Horizontal, Vertical and Diagonal subbands for all images are having low standard deviation value while the Approximate subband having a higher standard deviation value.

Table 1
Standard Deviation Value for Each Subband in Test Images

Image	Standard Deviation Value			
	Horizontal	Vertical	Diagonal	Approximate
Lena	3.4745	5.5370	2.7679	47.0973
Cameraman	4.9974	7.0070	2.4080	61.2227
Barbara	6.4231	6.7286	2.3291	52.0756
Mandrill	10.7944	8.0879	5.8885	36.5870

The low standard deviation value obtained at Horizontal, Vertical and Diagonal subbands is an indication that most of the value of the coefficient is low and it scattered around near zero value. These near-zero coefficients are actually representing the smooth region of an image.

In contrast, the high standard deviation value for coefficients in Approximate subband means that the coefficients in this subband spread in a very wide range. Most of them are high-valued coefficient that carries significant coefficients. Thus, thresholding is not suitable to be applied at this subband as it may harm the significant coefficients and lead to degradation of image quality.

So, at this point, the standard deviation value obtained at

Horizontal, Vertical and Diagonal subbands will be used as the threshold value for each respective subband. Table 2 shows the threshold value obtained for Horizontal, Vertical and Diagonal subbands of each test image.

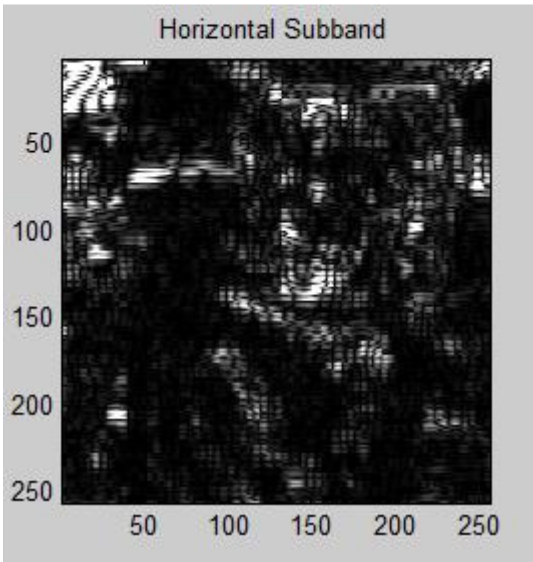
Table 2
The Threshold Value Obtained for Horizontal, Vertical and Diagonal Subbands of Each Test Image

Image	Threshold value		
	Horizontal, λ_H	Vertical, λ_V	Diagonal, λ_D
Lena	3	6	3
Cameraman	5	7	2
Barbara	6	7	2
Mandrill	11	8	6

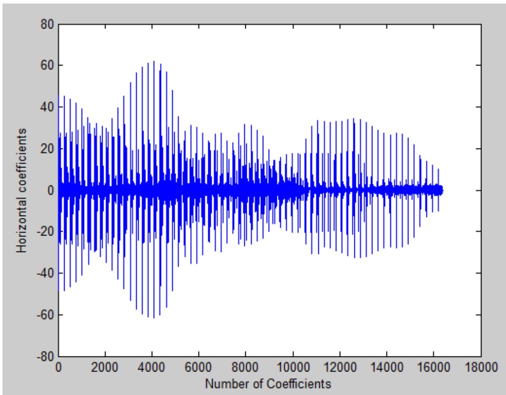
It also can clearly be seen in Figure 1 that by using the proposed Standard Deviation-Based Wavelet Coefficients Threshold Estimation Algorithm, only the near-zero valued coefficients were discarded, while the significant valued coefficients that carry the significant data such as fine details and edges were preserved

To indicate that the significant fine details and edges of the image were not distracted, the edge map analysis was done. The edge map of an image will reflect the strength of the edge. As can be seen in Figure 1, the threshold value for Horizontal subband, λ_H of Barbara image is 6. So, all values whose magnitude are less than absolute 6 have been set to 0 and they appear as a uniform black background in image.

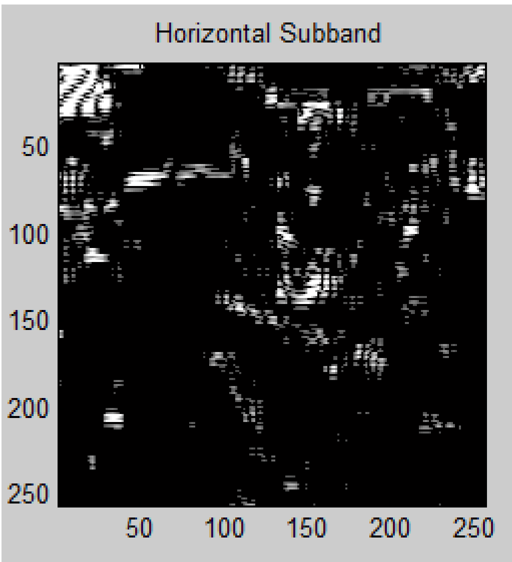
However, the wavelet coefficients valued higher than 6 was retained and is represented as a white stripe in edge map image. Here, the only background of the image affected after the thresholding process where a larger area of a black background has produced an indication of the larger number of zero valued coefficients formed caused by the thresholding process.



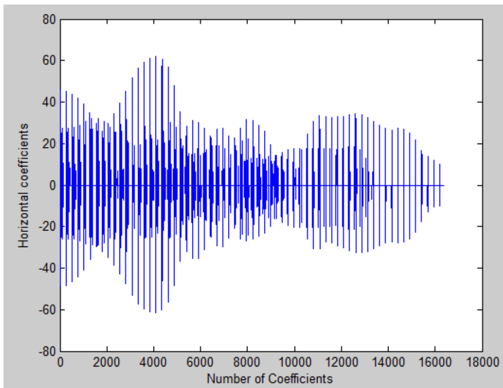
(a) Horizontal Edgemap Before Thresholding



(b) Horizontal Wavelet Coefficient Before Thresholding



(c) Horizontal Edgemap After Thresholding



(d) Horizontal Wavelet Coefficient After Thresholding

Figure 1: Edgemap and Wavelet Coefficient representation before and after thresholding on Barbara's Horizontal Subband.

To prove the performance of visual appearance of the final reconstructed images, the PSNR analysis was done. Table 3 shows the result of PSNR analysis on the test images. From the test done, the images compressed using the proposed compression algorithm shows an excellent PSNR value which is more than 40 dB for all images. Compared to the image reconstructed by using EZW, SPIHT, WDR and ASWDR compression algorithms, the PSNR value obtained was lesser than 40 dB.

Table 3
PSNR Value Comparison Between Wavelet-Based Compression Algorithms with Proposed Compression Algorithm

Image	EZW	SPHIT	WDR	ASWDR	Proposed
Lena	32.84	32.11	32.84	32.84	**46.14**
Cameraman	37.58	32.57	37.58	37.58	**45.43**
Barbara	33.95	28.86	33.95	33.95	**46.53**
Mandrill	29.72	28.79	29.72	29.72	**44.36**

Higher PSNR value indicates the improvement of image quality. Besides, images with a PSNR value of more than 40dB is considered as very good (Yadav *et al.*, 2012) because at this point, the normal human eyes observation cannot virtually differentiate between the original and reconstructed image [31]. This PSNR value also indicates that no blurring or image quality degradations appear on the reconstructed image.

This result also confirms that even though the proposed Standard Deviation-Based Thresholding Algorithm eliminates some of the coefficients, it does not degrade the image quality since the significant coefficients were still retained, thus preserving the significant data needed in reconstructing back the image. Moreover, it enhanced the image quality since the image contrast is enhanced because of the larger difference between zero and significant coefficients.

V. CONCLUSION

In this research, a Standard Deviation-Based Thresholding Algorithm is proposed by introducing an improved thresholding algorithm that can estimate the suitable threshold value by measuring the dispersion trend or characteristic of wavelet coefficients in each detail subband using standard deviation concept. Throughout the experiments done, it was found that suppressing the near-zero coefficients using the proposed Standard Deviation-Based Thresholding Algorithm benefited in eliminating as much as possible near zero coefficients to increase compression ratio without harming the significant coefficients.

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