

A New Psychovisual Threshold Technique in Image Processing Applications

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Highlights: A psychovisual threshold is developed based on the psychoacoustic quiet threshold. Psychovisual threshold is obtained from quantitative experiments by evaluating the just noticeable difference (JND) at various frequency orders. Psychovisual threshold is suitable to be implemented in image compression and image watermarking applications. In image compression, the experimental results produced largely free artifacts in the visual output image and better image quality at the higher compression rate than JPEG image compression. This technique is suitable to be used in image watermarking, the experimental results indicated that the proposed scheme can achieve high imperceptibility and robustness.

Key words: *psychovisual, image compression, image watermarking, bit allocation, robustness, imperceptibility.*

Introduction

An image contains large amount of redundant data in smooth areas where adjacent image pixels have almost the same values (Ernawan et al., 2016b). It means that the image pixels are highly correlated. An image contains subjective redundancy which is determined by




the human visual system. The visual image redundancy relatively is not perceived in perception of the human visual system. The human visual system perceives the significant dominant image signals. The human eye presents some tolerance to the distortion, depending upon the image content and viewing conditions. The human visual system does not perceive the difference between adjacent image pixels. The psychovisual redundancy can be ignored by an optimal of frequency image signals to the image quality. The psychovisual redundancy is eliminated in the lossy data compression by the quantization process (Ernawan et. al., 2013a).

Recently, the psychovisual experiment has become an important issue and a big challenge in image compression and image watermarking. Crandall et. al., (2013) proposes the psychovisual image compression technique during encoding to discard psychovisually unnecessary bits from the image pixels. The psychovisual compression process is achieved based on the characteristics of the pixel data. The psychovisual image compression techniques that are disclosed that compress pixel data by a fixed compression ratio with small or no perceptual loss of the details in the image information (Crandall et. al., 2013).

The contribution of the DCT coefficient to the reconstruction error were measured in real and graphical images and analysed as an initial psychovisual threshold (Abu et. al., 2013a; Ernawan et. al., 2013b). This threshold can be utilized to determine the location and strength of the watermark (Abu et. al., 2013c; Ernawan, 2016; Ernawan et. al., 2016a; Ernawan et. al., 2016c). Watermark insertion under the constraint of the psychovisual threshold was chosen in order for the watermark to be invisible to the human visual.





Psychovisual in image watermarking exploits the characteristic of Human Visual System (HVS) in effectively embedding a robust watermark.

Proposed Technique

The characteristics of DCT coefficients against reconstruction errors prescribe the psychovisual threshold (Abu et. al., 2013b; Emawan, et. al., 2014b) for luminance as shown in Figures 1. A green curve and a blue curve represent the average error reconstruction based on minimum and maximum JPEG quantization values for each frequency order, respectively. An ideal average reconstruction error score of an incrementing DCT coefficients on each frequency order for luminance is shown as a red curve.

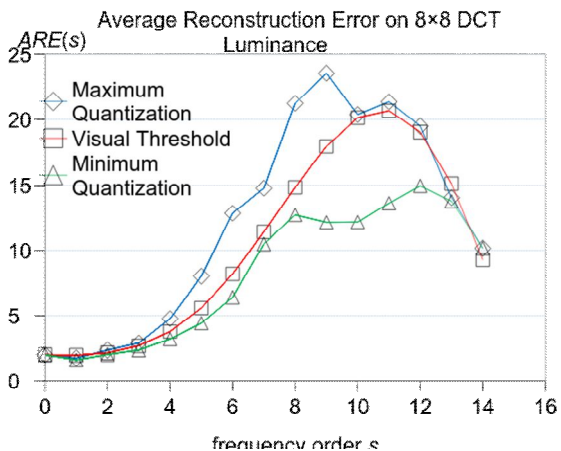


Figure 1: Average reconstruction error of incrementing DCT coefficients on 8x8 DCT luminance

The average reconstruction error of incrementing DCT coefficients and TMT coefficients for luminance are shown in Figures 1 and 2. The effect of the incrementing



frequency coefficients to the reconstruction error based on minimum and maximum of the default JPEG quantization tables for a given order zero to order fourteen is visualized as curves. The sensitivity of the frequency coefficients on each frequency order against reconstruction errors produces an acceptable visual quality for the human visual system (Ernawan et. al., 2014c; Ernawan et. al., 2014d).

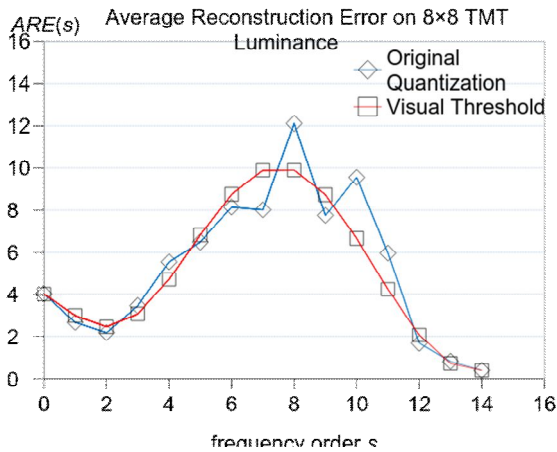


Figure 2: Average reconstruction error of incrementing TMT coefficients on 8x8 TMT luminance



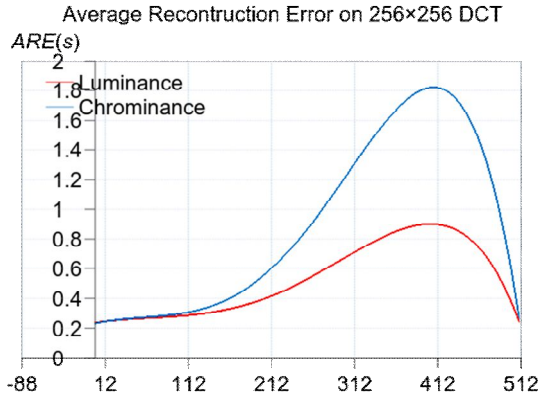


Figure 3: Average reconstruction error of incrementing DCT coefficients on 256x256 DCT luminance and chrominance

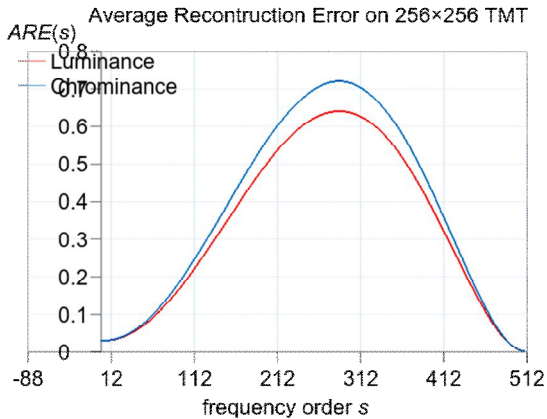


Figure 4: Average reconstruction error of incrementing TMT coefficients on 256x256 TMT luminance and chrominance



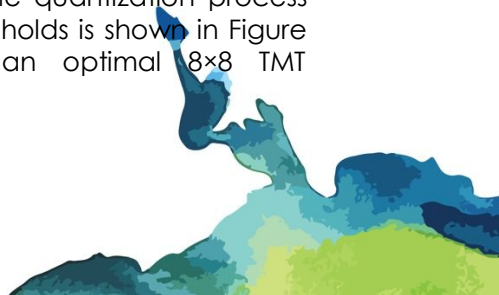
An ideal average reconstruction error of incrementing 256×256 DCT coefficients and 256×256 TMT coefficients are shown in Figures 3 and 4. These ideal smooth curves give an optimal balance between the quality on image reconstruction and the bit rates in image compression.

Results and Discussion

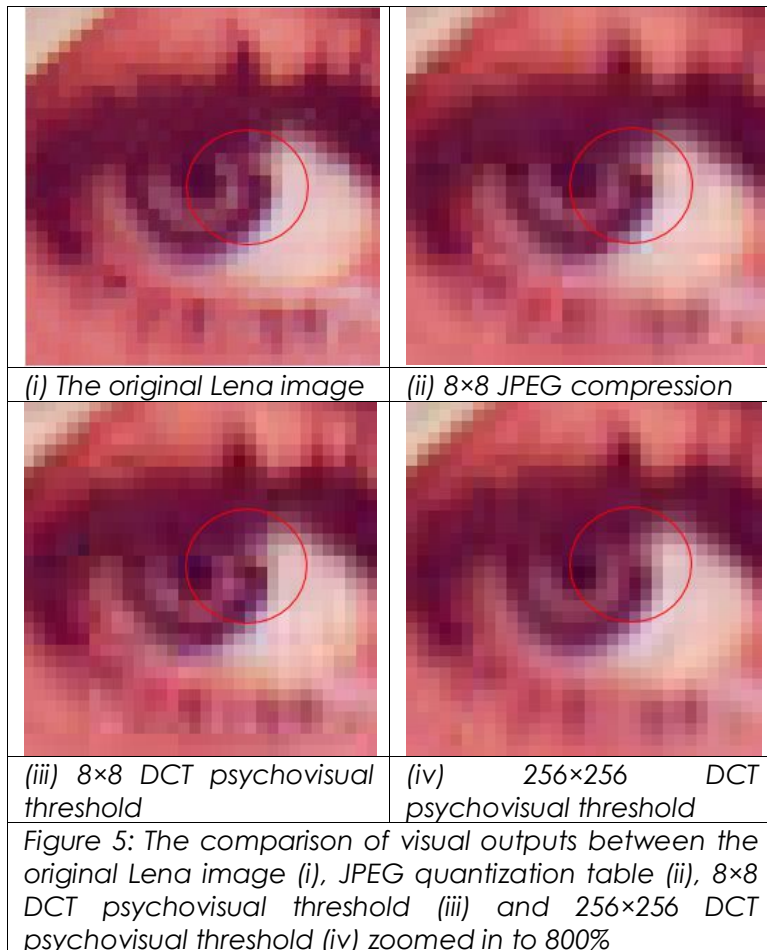
The experiments of the psychovisual threshold are conducted on JPEG compression and TMT image compression. The psychovisual threshold provides an efficient image reconstruction at lower average bit length of Huffman code. The large discrete transform reduces the correlation along the blocks. The psychovisual threshold on large discrete transform scheme improves the quality of image reconstruction and the efficient image coding.

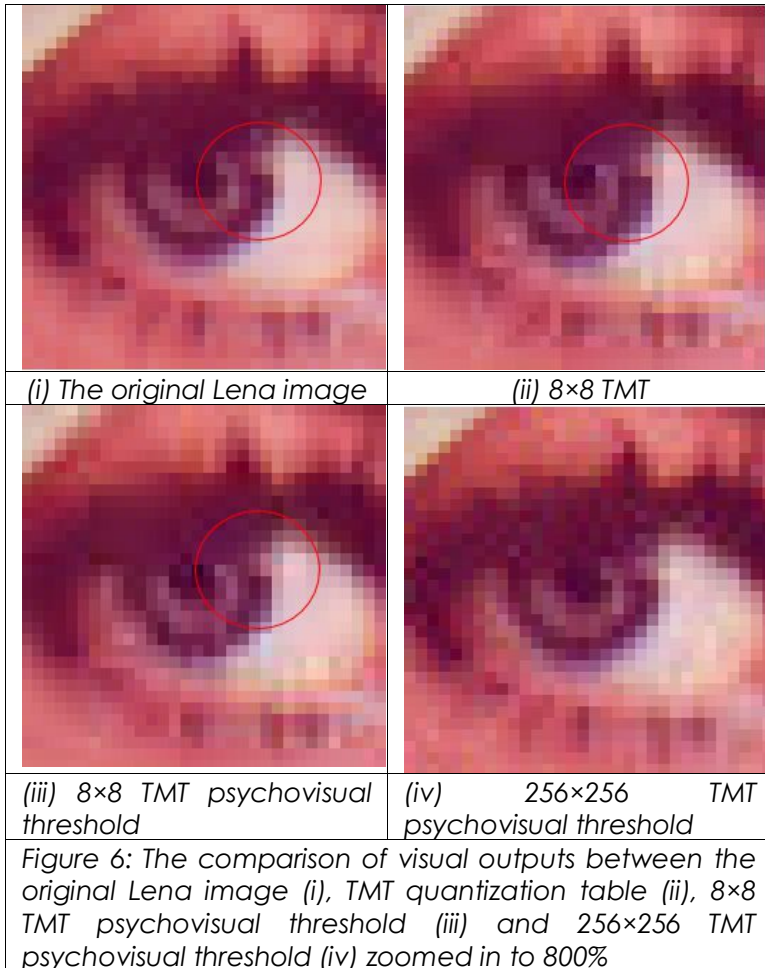
An experiment on the impact of the psychovisual threshold in image compression for Lena image is shown in Figure 5. The image output from JPEG image compression as depicted on the Figure 5(ii) contains blocking effect along the boundary blocks under regular 8×8 discrete transform. At the same time, the smoother 256×256 quantization tables from the psychovisual threshold manage to overcome the blocking effects along the boundary blocks. Referring to Figure 5(iv) above, the smoother 256×256 DCT quantization tables from the psychovisual threshold produce less artifact images. The 256×256 DCT quantization table provides better quality of the image output than 8×8 DCT psychovisual threshold and standard JPEG compression.

The output Lena image after the quantization process based on TMT psychovisual thresholds is shown in Figure 6. Referring to Figure 6(iii), an optimal 8×8 TMT

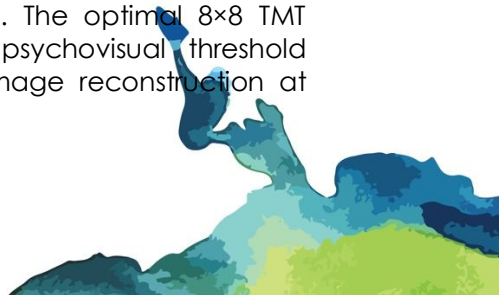


quantization tables from the psychovisual threshold produce brighter pupil on the right eye of the Lena image than the previous default 8×8 TMT quantization table as depicted on the red circle.





The effectiveness of the psychovisual threshold in TMT image compression gives a significantly better performance in comparison to DCT especially on the quality of image reconstruction. The optimal 8x8 TMT quantization tables from the psychovisual threshold produces a better quality of image reconstruction at



lower bit rates than previous 8×8 TMT quantization tables and default JPEG quantization tables. The finer 256×256 TMT quantization tables from the psychovisual threshold produce a higher statistical score on the quality of image reconstruction than originally 8×8 TMT quantization tables as shown in Table 1. In addition, the image reconstruction from 256×256 TMT quantization tables provides lower reconstruction error than 256×256 DCT quantization tables and default JPEG quantization tables. The smoother 256×256 TMT quantization tables from the psychovisual threshold are used as an example to illustrate the efficient results.

Table 1: The average quality of image reconstruction from JPEG image compression for 40 real images and 40 graphical images

Method	40 Real Images				40 Graphical Images			
	Full Error	MSE	PSNR	SSIM	Full Error	MSE	PSNR	SSIM
Default 8×8 JPEG quantization tables	5.535	70.964	31.190	0.956	5.648	92.711	31.636	0.957
8×8 DCT quantization tables from the psychovisual threshold (Ernawan and Nugraini, 2014)	5.499	69.520	31.252	0.955	5.445	82.237	31.880	0.957
256×256 DCT quantization tables from the psychovisual threshold (Abu and Ernawan, 2015)	5.074	51.841	32.363	0.961	5.050	59.625	33.421	0.960
Default 8×8 TMT quantization tables	5.258	58.159	31.372	0.947	4.840	61.036	32.274	0.952



8×8TMT quantization tables from the psychovisual threshold (Ernawan et. al., 2014a)	5.246	57.448	31.379	0.946	4.767	56.745	32.363	0.951
256×256TMT quantization tables from the psychovisual threshold (Abu and Ernawan, 2014)	4.671	39.777	32.572	0.948	4.280	36.891	33.704	0.949

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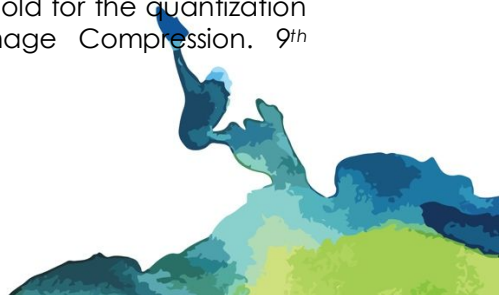
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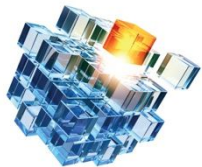
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