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Course Project Final Report

Blind Measurement of Blocking Artifact in Images

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Abstract

Blocking effect is the most annoying artifact in block transform-coded image/video. Objective measurement of blocking artifact plays an important role in the development, optimization, and assessment of image/video coding systems. It is also very useful for the design and evaluation of the post-processing algorithms at the decoding side. In this report, a deterministic approach is proposed that can blindly measure blocking artifact in blocky images without the reference of the original ones. The new metric is developed by using the second-order and the third-order statistical features of the image. Furthermore, by considering human visual masking effects, the metric is modified to comply with human perception. JPEG compressed images are used to test the measurement systems.

Keywords: Image Quality, Blocking Artifact, Block Transform Image Coding, Power Spectrum, Bi-spectrum, Human Visual System

I. INTRODUCTION

Block transform-based techniques are widely adopted by many current image and video coding standards, such as JPEG, MPEG-1, MPEG-2, H. 261 and H. 263. In order to achieve low bit rates, quantization is normally used during encoding to compress the transform coefficients of the original image/video. The quantization process is lossy. As a result, the compressed image/video cannot be exactly reconstructed at the decoding side. The decompressed image/video exhibit various kinds of distortion artifacts such as blocking, blurring and ringing. The human visual sensitivity to different types of artifacts is quite different. It is shown that the blocking effect, and its propagation through reconstructed video sequences, are the most significant of all coding artifacts [1].

Blocking artifact measurement algorithm plays an important role in the design of image/video coding systems. It can embed into the encoder to optimize the coding parameters or control the bit allocation. It may also be employed by the post-processing algorithms in the decoder to improve the decompressed image quality. In recent years, a large number of blocking artifact reduction algorithms have been proposed that are applied in either the encoders [2] or the decoders [3-6]. However, most of them simply use the Mean Squared Error (MSE) as the distortion measure. Since MSE is not good for image quality assessment [7], several better distortion measures have been proposed [8-9]. Nevertheless, in the absence of the original images, these algorithms cannot be used because the distortion errors cannot be computed without the reference images. In such cases, *blind blocking artifact measurement* algorithm is necessary. It is especially useful for the assessment and design of post-processing algorithms since the original images are not available at the receiver side.

Recently, two similar blind blocking artifact measurement algorithms were proposed independently [1, 10]. They both use a weighted mean-squared difference along block boundaries as the blockiness measure, where the weights are obtained according to human visual masking effects. A drawback of these methods is that they cannot distinguish how much of the gray level difference between block boundaries is due to real blocking discontinuity or the oscillation of the original signal itself. In this report, a new blind blocking distortion metric is proposed by employing the 2nd- and the 3rd-order statistical features of the image. The metric can also be modified to comply with human visual perception by merging the masking effects.

II. THE BLIND MEASUREMENT APPROACH

The proposed blind blocking artifact measurement system is shown in Fig. 1. For simplicity, we assume the size of the test image is $M\times M$ and the block size is 8×8, where M is a multiple of 8. The blocking effect is measured in vertical and horizontal directions separately. In consideration of the vertical blockiness, we first take difference along each row and apply the absolute operator. Suppose the test image is represented by a matrix $\boldsymbol{f}$ = $\{f[i, j]; 0 \le i, j \le M-1\}$, then this process results in an residue image $\boldsymbol{g}$ = $\{g[i, j]; 0 \le i, j \le M-1\}$, where

$$g[i, j] = \begin{cases} 0 & 0 \le i \le M-1,\ j = 0 \\ \left| f[i, j] - f[i, j-1] \right| & 0 \le i \le M-1, 1 \le j \le M-1 \end{cases}. \quad (1)$$

The $\boldsymbol{g}$ image is then rearranged to a 1-D signal $\boldsymbol{s} = \{s[n]; 0 \le n \le M^2 - 1\}$ by

$$s[Mi + j] = g[i, j]; \quad 0 \le i, j \le M-1 \quad (2)$$

In the next step, we estimate the power spectrum of the signal $\boldsymbol{s}$ using the Fast Fourier Transform (FFT). A segment $\boldsymbol{x}^{(k)} = \{x[n] = s[n_k + n]; 0 \le n \le N-1\}$ with a length of N is extracted from the signal $\boldsymbol{s}$, where N is a power of 2 and n_k is the starting point of $\boldsymbol{x}^{(k)}$. After applying FFT on $\boldsymbol{x}^{(k)}$, we get $\boldsymbol{X}^{(k)}$ = $\{X^{(k)}[l]; 0 \le l \le N-1\}$. The power spectrum $\boldsymbol{P}^{(k)}$ = $\{P^{(k)}[l]; 0 \le l \le N/2\}$ of this segment is then computed as

$$P^{(k)}[l] = \begin{cases} 2\left|X^{(k)}[l]\right|^2 & 1 \le l \le N/2-1 \\ \left|X^{(k)}[l]\right|^2 & l = 0, N/2 \end{cases}. \quad (3)$$

Suppose total of L segments are computed, then the overall estimated power spectrum $\boldsymbol{P}$ = $\{P[l];\ 0 \le l \le N/2\}$ is the average of all the segment estimations:

$$P[l] = \frac{1}{L}\sum_{k=1}^{L} P^{(k)}[l] \quad 0 \le l \le N/2\,. \tag{4}$$

Fig. 2 (a) is the result of the power spectrum of the rows of a JPEG compressed ‘Lena’ image. It is interesting to compare it with the power spectrum of the original image of ‘Lena’ (shown in Fig. 2 (b)) after the same process mentioned before. Intuitively, the blocking artifact is characterized by the several peaks on the N/8, N/4, 3N/8, N/2 positions along the power spectrum. A straightforward way to measure the blocking effect is to approximate the power spectrum using a smoothly varying curve and count the powers of the special frequency components above that curve. This measure is good for most cases. However, when the image signal itself has a special frequency distribution that disturbs the characteristic frequency components, it cannot ensure a robust measurement. An example is given by Fig. 3, which is obtained from ‘Barbara’ image.

Fortunately, more cues on blockiness can be obtained by going to the 3rd-order statistics. For a given segment $\boldsymbol{x}^{(k)}$, a bi-spectrum estimation $\boldsymbol{B}^{(k)} = \{B^{(k)}[l_1,l_2];\ [l_1,l_2]\in\Sigma\}$ is given by

$$B^{(k)}[l_1,l_2] = X^{(k)}[l_1+l_2]X^{(k)*}[l_1]X^{(k)*}[l_2]; \qquad [l_1,l_2]\in\Sigma\,, \tag{5}$$

where $\Sigma = \{[l_1,l_2]\,|\,0\le l_1 \le N/4,\ 0\le l_2 < l_1 \ \ or\ \ N/4+1 \le l_1 < N/2,\ 0 \le l_2 < l_1 - N/4\}$ is defined as a triangular region according to the symmetric properties of the bi-spectrum [11]. The overall estimation of the bi-spectrum $\boldsymbol{B}$=$\{B[l_1,l_2];\ [l_1,l_2]\in\Sigma\}$ is then given by:

$$B[l_1,l_2] = \frac{1}{L}\sum_{k=1}^{L} B^{(k)}[l_1,l_2]; \qquad [l_1,l_2]\in\Sigma \tag{6}$$

An example of the bi-spectrum of the test image is shown in Fig. 4. The bi-coherence value

$$\gamma^2_{XXX}[l_1,l_2] = \frac{\left|B[l_1,l_2]\right|^2}{\frac{1}{L}\sum_{k=1}^{L}\left|X^{(k)}[l_1+l_2]\right|^2 \cdot \frac{1}{L}\sum_{k=1}^{L}\left|X^{(k)}[l_1]X^{(k)}[l_2]\right|^2}; \qquad [l_1,l_2]\in\Sigma \tag{7}$$

is a normalized version of the bi-spectrum value. It is bounded by 0 and 1 and has the physical meaning of how much the frequency components on l_1, l_2 and l_1+l_2 are correlated.

We define our new vertical blocking metric as the sum of the power of the character frequency components multiplied by the bi-coherence value between them:

$$M_{Bv} = C \cdot \gamma^2_{XXX}[N/8, N/4] \cdot (P[N/8] + P[N/4] + P[3N/8]) \quad (8)$$

where C is a constant set to 4/3. Using the similar method, we can get the horizontal blocking metric M_{Bh}. Finally, the overall blockiness of the test image is defined by:

$$M_B = 0.5M_{Bv} + 0.5M_{Bh} . \quad (9)$$

Here we assume the vertical and horizontal blocking measures are of the same importance.

III. CONSIDERATION OF HUMAN VISUAL MASKING EFFCTS

Various human visual system features are correlated with perceptual image/video quality [12]. In this report, only the local luminance and local activity masking effects are considered because they are the most significant with regard to the perception of blocking artifact.

A modified version of our blocking artifact measurement system considering masking effects is shown in Fig. 5. Since the masking effects are spatially varying, we first evaluate the strength of the local masker according to the local background luminance and local activity of the test image. The output of this procedure is a masker map $\boldsymbol{m} = \{m[i, j];\ 0 \le i, j \le M-1\}$ of the test image, which indicates human visual sensitivity to local luminance differences. The algorithm to generate the masker map is similar to that in [13], where it is used to compute the just-noticable-distortion (JND) map for perceptual image coding. The masker map is then used to weight the above mentioned residual $\boldsymbol{g}$ image. As a result, the 1-D signal $\boldsymbol{s}$ becomes

$$s[Mi + j] = m[i, j] \cdot g[i, j]; \quad 0 \le i, j \le M-1 \quad (10)$$

As shown in Fig. 5, the processes that followed are the same as those in the original measurement system. Finally, we achieve the modified blocking measure M_{HB}.

IV. IMPLEMENTATION AND CONCLUSION

Due to the huge volume of the image data, the calculation of the bi-spectrum is a very high computational burden. This is one of the major reasons that impede the application of the third or even higher- order statistical methods to image processing. Fortunately, in our systems, only the bi-coherence values at certain frequency positions need to be computed. This keeps our algorithms fast. Our proposed algorithms are tested using the JPEG compressed images. The blocking measurement results on “Lena” and “Barbara” images are shown in Fig. 6.

In conclusion, this report proposes a new blocking effect measurement system and its modified version combining masking effects. Its main contributions include: 1) It presents a new *blind* image blocking artifact assessment method, while most of the other image quality measures need the reference images. 2) It introduces a new application that uses *higher-order statistics* (HOS) in image processing, whereas the previous HOS applications in the literature is limited in image decomposition, image coding, image deconvolution and pattern recognition [14].

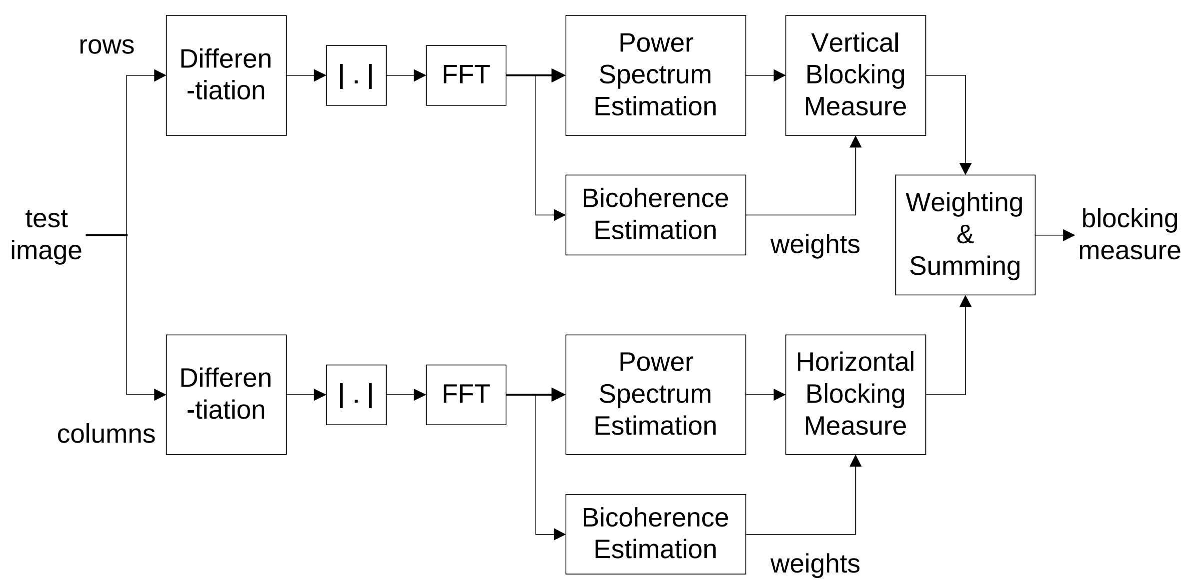
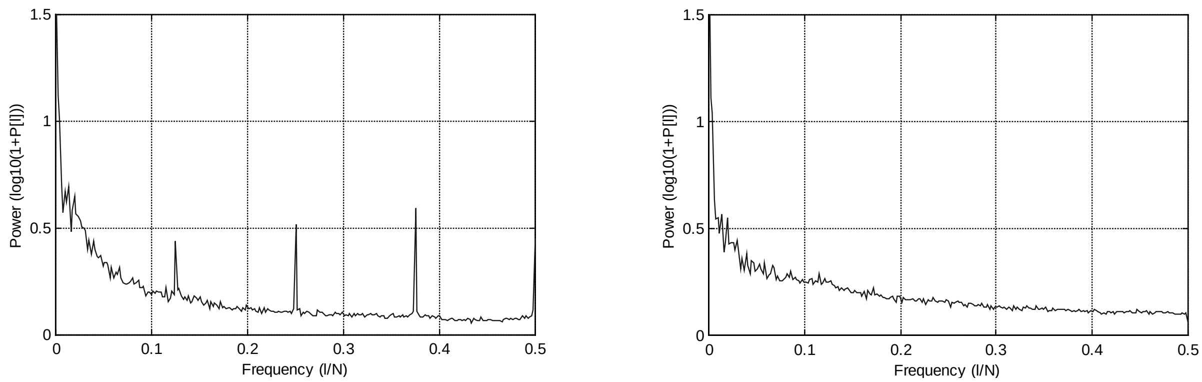
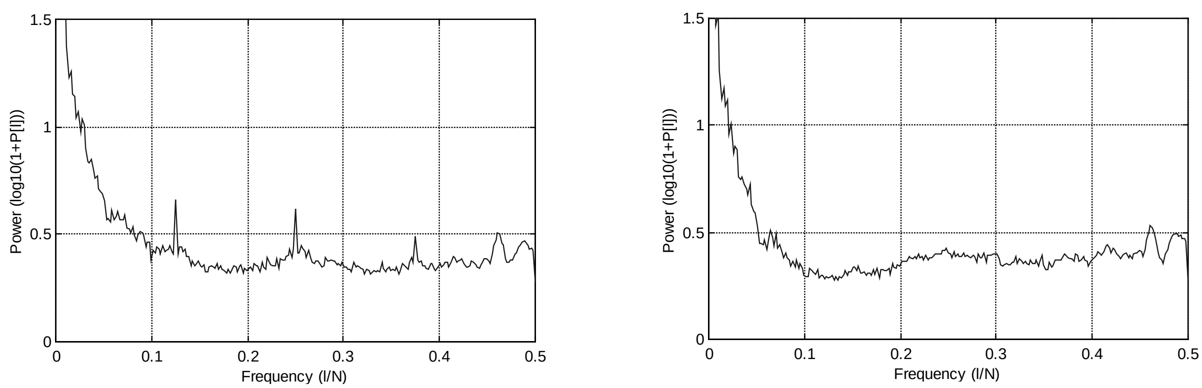


Fig. 1. The blind blocking artifact measurement system



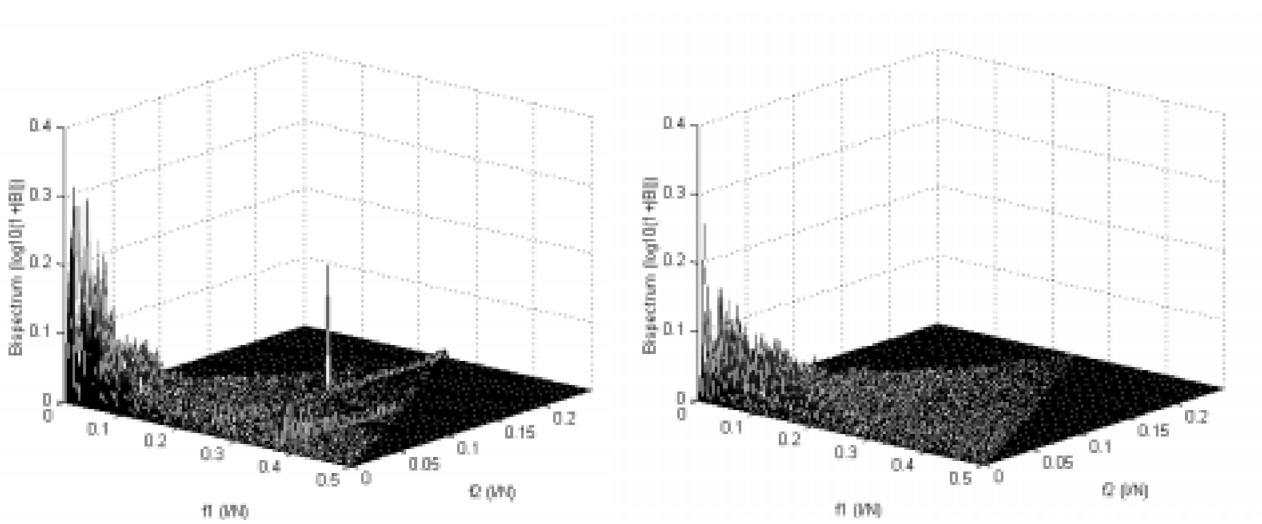
(a) (b)

Fig. 2. Power spectrum estimation results. (a) JPEG compressed 'Lena' image; (b) Original 'Lena' image.



(a) (b)

Fig. 3. Power spectrum estimation results. (a) JPEG compressed 'Barbara' image; (b) Original 'Barbara' image.



(a) (b)

Fig. 4. Bispectrum estimation results. (a) From blocky 'Lena' image; (b) From original 'Lena' image.

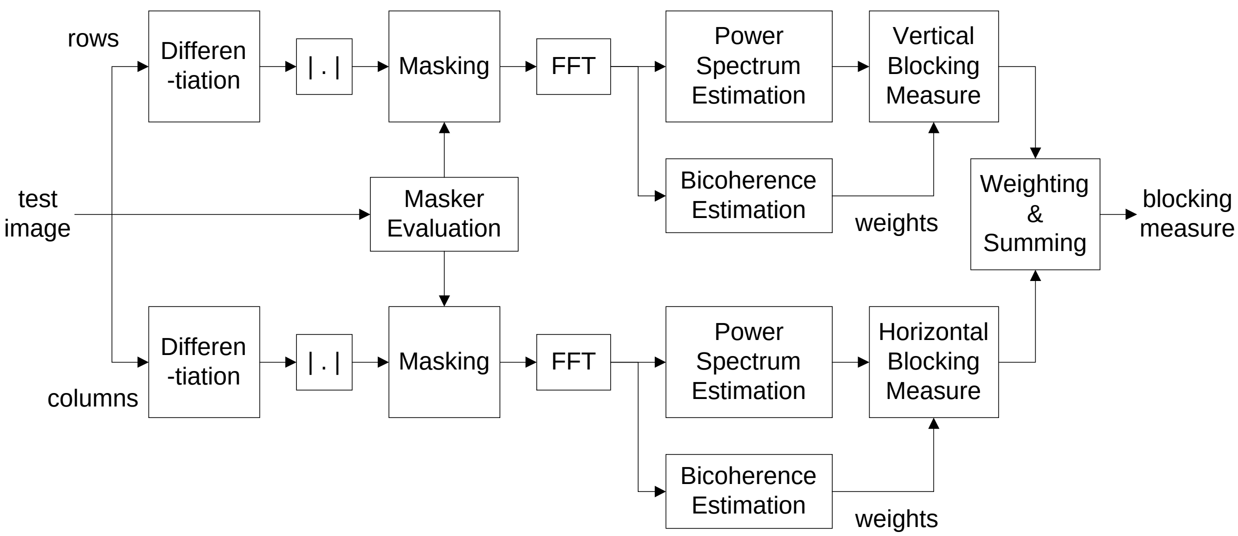
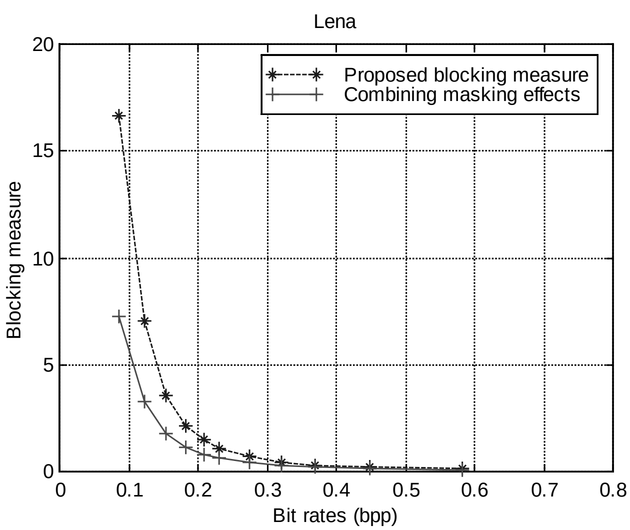
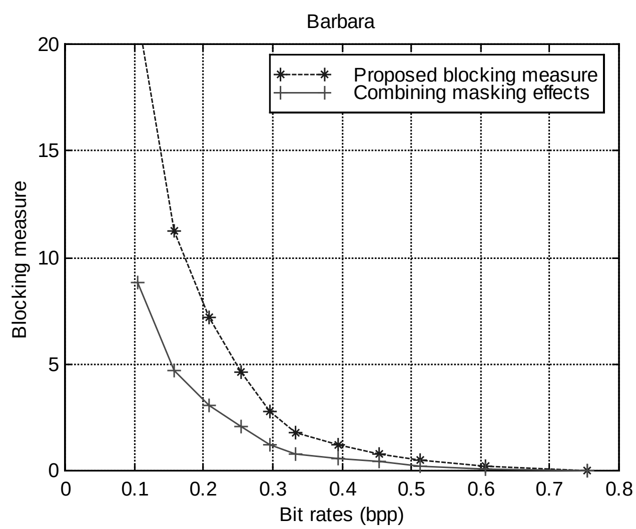


Fig. 5. Modified blind blocking artifact measurement system combing human visual masking effects



(a)



(b)

Fig. 6. Blocking artifact measurement results of JPEG compressed images. (a) 'Lena' image; (b) 'Barbara' image.

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