BLIND MEASUREMENT OF BLOCKING ARTIFACTS IN IMAGES

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ABSTRACT

The objective measurement of blocking artifacts plays an important role in the design, optimization, and assessment of image and video coding systems. We propose a new approach that can blindly measure blocking artifacts in images without reference to the originals. The key idea is to model the blocky image as a non-blocky image interfered with a pure blocky signal. The task of the blocking effect measurement algorithm is then to detect and evaluate the power of the blocky signal. The proposed approach has the flexibility to integrate human visual system features such as the luminance and the texture masking effects.

1. INTRODUCTION

Block transform coding has been widely adopted in many current image and video compression standards such as JPEG, H.261, H.263, MPEG-1, MPEG-2 and MPEG-4. In order to achieve low bit rates, quantization is normally used during encoding to compress the transform coefficients. The quantization process is lossy. As a result, the decompressed image and video exhibit various kinds of distortion artifacts such as blocking, blurring and ringing. The human visual sensitivity to different types of artifacts is very different. The blocking effect is usually the most significant among them, especially at low bit rate compression.

Blocking artifact measurement algorithms have an important role to play in the design of image and video coding systems. By embedding such an algorithm into the encoder, it becomes possible to optimize the coding parameters or control the bit allocation to reduce blocking artifacts. It may also be employed by the post-processing algorithms in the decoder to improve the decompressed image quality. In recent years, many blocking artifact reduction algorithms have been proposed [1-3]. However, most of them simply use the mean squared error (MSE) as the distortion measure. Since the MSE is not good for perceptual image quality assessment [4], several improved distortion measures have been proposed [5, 6]. All of these techniques require access to the original images. We propose *blind blocking artifact measurement*, which is calculated without the reference images. It would be especially useful for the assessment and design of post-processing algorithms since the original images are not available at the receiver side.

The blind blocking artifact measurement algorithms proposed in [7] and [8] both used a weighted mean-squared difference along block boundaries as the blockiness measure. Such kind of methods 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. Even the original image might be evaluated as, to some extent, blocky.

In this paper, we model the blocky image as a non-blocky image interfered with a pure blocky signal. The goal of the blocking effect measurement algorithm is then to detect and estimate the power of the blocky signal. Such a general model can easily combine with the human visual luminance and texture masking effects.

2. THE BLIND MEASUREMENT APPROACH

For simplicity, we assume the size of the test image is $M \times M$ and the block size is $B \times B$, where M is a multiple of B. We also assume B=8 because this is the most frequently used block size for block transform based image coding. Before introducing our blocking measurement system, we first define an ideal 1-D blocky signal $\boldsymbol{b}$ as

$$\begin{cases} b[iB] = b[iB+1] = \cdots = b[iB+B-1] \\ b[(i+1)B] = b[iB] + V[i]\Delta \end{cases} \quad i = 0, 1, 2, \cdots$$

where $V[i]$ is a random variable that takes on the value of either 1 or –1, and Δ is the step size. A typical blocky signal is shown in Fig. 1(a). The blockiness measure of this ideal blocky signal should be independent of $V[i]$. To remove the influence of $V[i]$, we first take the absolute difference along the signal:

$$d[i] = |b[i] - b[i-1]| \quad i = 1, 2 \cdots$$

which is shown in Fig. 1(b). We then define the blockiness measure as the power of the sequence $\boldsymbol{d}$ = $\{d[i];\ i = 0, 1, 2, \cdots\}$:

$$M_B = \frac{\Delta^2}{B}\cdot$$

Think of a blocky image as a non-blocky image interfered with an ideal blocky signal. The blocking measurement problem is then to detect the blocky signal and estimate its power.

Our measurement system is shown in Fig. 3. The blocking effect is measured in the vertical and horizontal directions separately. In consideration of the vertical blockiness, we first compute the absolute differences along each row. Suppose the test image is $\boldsymbol{f}$ = $\{f[i,j];\ 0 \le i,j \le M-1\}$, then the vertical difference image is $\boldsymbol{g} = \{g[i,j];\ 0 \le i,j \le M-1\}$, where

$$g[i,j] = \left| f[i,j] - f[i,j-1] \right| \quad 0 \le i,j \le M-1\cdot$$

$\boldsymbol{g}$ is then rearranged to a 1-D signal $\boldsymbol{s}$:

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

It is difficult to distinguish directly the blockiness power from the signal $\boldsymbol{s}$. Fortunately, more clues can be obtained when we go to the frequency domain. We estimate the power spectrum of $\boldsymbol{s}$ using the Fast Fourier Transform (FFT). A segment $\boldsymbol{x}^{(k)}$ = $\{x[n] = s[n_k + n];\ 0 \le n \le N-1\}$ of length N is extracted from the signal $\boldsymbol{s}$, where N is a power of 2 and n_k is the starting point of $\boldsymbol{x}^{(k)}$. We denote the FFT of $\boldsymbol{x}^{(k)}$ to be $\boldsymbol{X}^{(k)}$ = $\{X^{(k)}[l];\ 0 \le l \le N-1\}$. The power spectrum $\boldsymbol{P}^{(k)}$ = $\{P^{(k)}[l];\ 0 \le l \le N/2\}$ of this segment is then estimated as

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

Suppose that a 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 these estimates:

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

In Fig. 2, we show the original and a JPEG compressed images of 'Lena'. The estimated power spectra of the two images are shown in Fig. 4 and Fig. 5, respectively. It can be observed that they are of very similar shape, except for the peaks in the power spectrum curve of the JPEG compressed image at the N/8, 2N/8, 3N/8, 4N/8 positions. A combined view of those peaks provides us with a signature of blockiness.

In a blind blocking artifact measurement system, only the power spectrum curve of the blocky image is available. In order to provide a blockiness measure, we approximate the power spectrum using a smoothly varying curve, and calculate the powers of the feature frequency components above that curve. A median filter is employed to smooth the power spectrum curve:

$$P_M[l] = Median\{P[l-K], \cdots, P[l], \cdots, P[l+K]\}\cdot$$

The size (2K+1) of the median filter depends on N. In our experiments, N is 512 and K is 4. The smoothed version of the power spectrum curve should maintain the values at the feature frequencies. It is given by

$$P_S[l] = \begin{cases} P[l] & l = N/8,\ 2N/8,\ 3N/8,\ or\ 4N/8 \\ P_M[l] & otherwise \end{cases}\cdot$$

The smoothed power spectrum curve of the JPEG compressed image is shown in Fig. 7. The vertical blockiness measure corresponds to the power of the blocky signal can be evaluated as

$$M_{Bv} = (P[0] - P_M[0]) + (P[\frac{N}{8}] - P_M[\frac{N}{8}]) + (P[\frac{N}{4}] - P_M[\frac{N}{4}]) + (P[\frac{3N}{8}] - P_M[\frac{3N}{8}]) + (P[\frac{N}{2}] - P_M[\frac{N}{2}])\cdot$$

However, usually the energy of the natural images is highly concentrated at the low frequency bands. This will disturb the blocky power measurement $(P[0] - P_M[0])$ at zero frequency. To avoid this, and also to maintain the total power estimation of the blocky signal, we define our vertical blocking measure as

$$M_{Bv} = \frac{8}{7}\left\{(P[\frac{N}{8}] - P_M[\frac{N}{8}]) + (P[\frac{N}{4}] - P_M[\frac{N}{4}]) + (P[\frac{3N}{8}] - P_M[\frac{3N}{8}]) + (P[\frac{N}{2}] - P_M[\frac{N}{2}])\right\}\cdot$$

Using the similar method, we can get the horizontal blocking measure M_{Bh}. Finally, the overall blockiness of the test image is given by

$$M_B = 0.5(M_{Bv} + M_{Bh})\cdot$$

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

3. INTEGRATION OF MASKING EFFECTS

Masking is the reduction in the visibility of one image component (the target) due to the presence of another (the masker) [9]. There are two kinds of masking effects that are significant with respect to the visual perception of the blocking artifacts. The first is the luminance masking or sometimes also called the light adaptation. In [10], it is shown that the human eyes are more sensitive to errors in mid-gray level areas. The second is the texture masking, which occurs when the maskers are complex textures or the masker and the target have similar frequencies and orientations.

Our blocking artifact measurement system is flexible to incorporate the masking effects. This is shown in Fig. 2. In masker evaluation, we first calculate the local background luminance and use the model in [10] to compute the luminance error visibility threshold. Since texture masking is sensitive to spatial directions, we evaluate the strength of the vertical and the horizontal texture maskers using the vertical and the horizontal luminance change operators in [10], respectively. The results of luminance and texture masking is then combined to a masker map $\boldsymbol{m}$ = $\{m[i,j];\ 0 \le i,j \le M-1\}$, which is used to scale the ***g*** image. The signal ***s*** then becomes

$$s[Mi+j] = g[i,j]/m[i,j]; \quad 0 \le i, j \le M-1 .$$

This is different from equation (1). The remaining parts of the blocking measurement system keep unchanged.

4. EXPERIMENTS AND DISCUSSIONS

We applied our algorithm to JPEG compressed gray scale images. The measurement results for JPEG compressed ‘Lena’ images are shown in Fig. 7. We also tested the proposed algorithms to non-blocky images (such as the original and the wavelet compressed images). As expected, the measurement results are almost all zeros.

Blockiness is a special kind of image feature in the sense that human eyes can easily feel it without observation of the original images. This implies that blockiness can be and should be detected and measured blindly. This paper provides a useful tool for blind blocking artifact assessment. In practical applications, very fast implementation can be easily obtained because actually only a small portion of the entire power spectrum needs to be computed.

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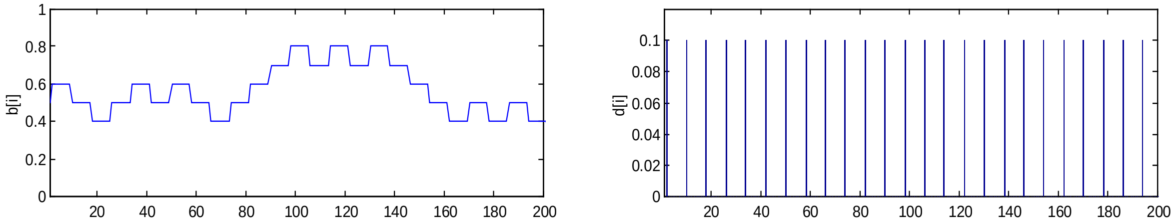

(a) (b)

Fig.1. (a) Ideal 1-D blocky signal; (b) Absolute difference signal.

(a) (b)

Fig.2. (a) Original ‘Lena’ image; (b) JPEG compressed blocky ‘Lena’ image.

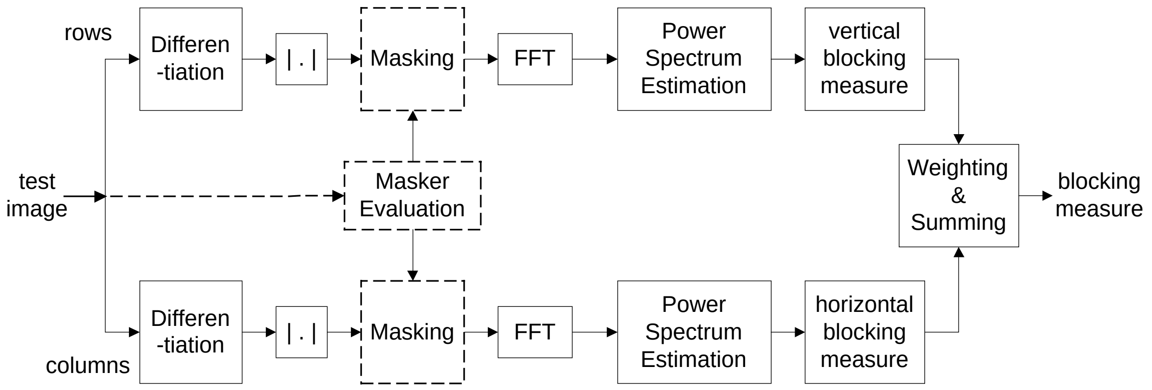

Fig. 3. The blind blocking artifact measurement system.

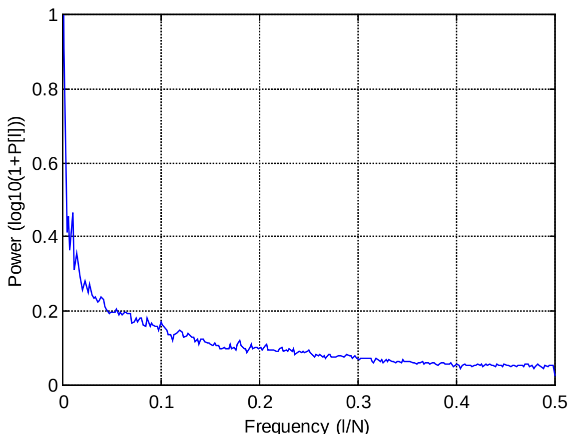

Fig.4. Power spectrum of the original 'Lena' image.

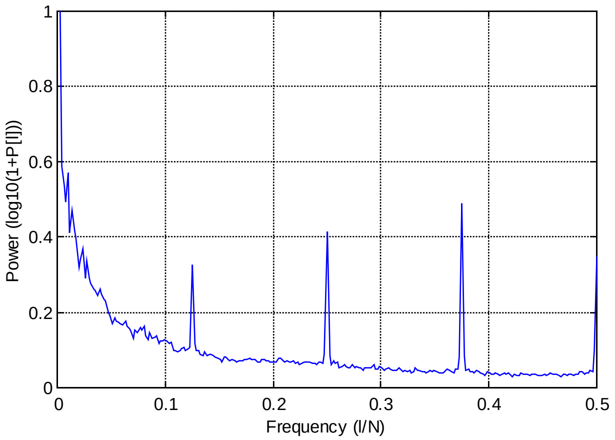

Fig.5. Power spectrum of the JPEG compressed 'Lena' image.

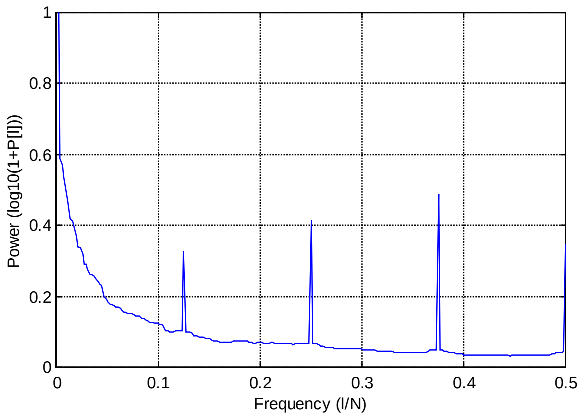

Fig.6. Smoothed power spectrum of the JPEG compressed 'Lena' image.

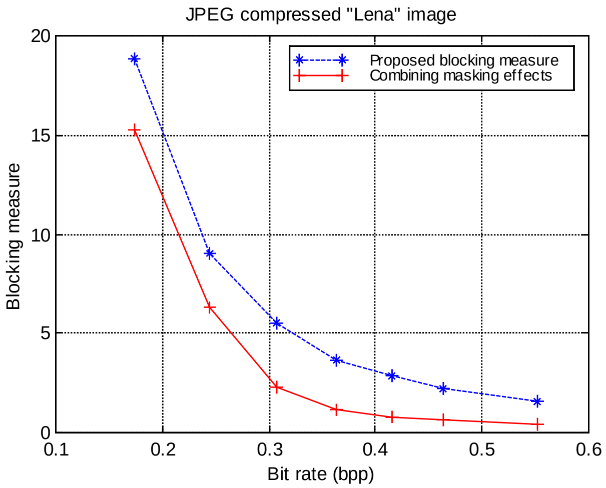

Fig.7. Blocking measurement results of JPEG compressed 'Lena' images.