IMAGE BLOCKINESS EVALUATION BASED ON SOBEL OPERATOR

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ABSTRACT

This paper presents a novel no-reference image blockiness index which exploits the properties of the Sobel operator. The blockiness index is a combination of two measures. The first quantifies the luminance variation of block boundaries pixels. The second quantifies the luminance variation of remaining pixels. Experimental results illustrating the performance of the proposed method show improvements over similar recently published methods.

1. INTRODUCTION

Objective image quality assessment is a very difficult task in image processing applications. Images coded using block-based DCT transform algorithms (e.g. JPEG, MPEG) exhibit blockiness artifacts. At high compression ratio, the decoded images show discontinuities near adjacent block boundaries.

Several techniques have been proposed [1], [2], [3], [4], [5], [6] to assess image and video quality. These techniques are divided into two classes: subjective and objective. Subjective measures estimate the visual quality by subjective tests, where a group of persons rate a series of images encoded with different coders or corrupted by several types of distortions [7]. Objective methods try to estimate the amount of distortion within an image using mathematical operations in the spatial or in the frequency image domain. Objective methods based on the human visual system (HVS) have been recently proposed for blockiness assessment [8], [9], [10], [11], [12], [13], [14]. In the last years, the Visual Quality Expert Group (VQEG) [15], [16] has collected, compared and evaluated a set of psychovisual methods specifically studied for video quality assessment.

A quality metric can be computed by a comparison between reference and compressed/distorted images or directly from the compressed/distorted ones. Subjective methods refer to these two approaches as *Double Stimulus Continuous Quality Scale* (DSCQS) and *Single Stimulus* (SSCQS), respectively. The corresponding objective methods are called *full-reference* and *no-reference*.

No-reference metrics are very useful when the reference data is not available, as in network video transmission or stored digital content evaluation (DVD, VideoCD).

A novel objective index for image blockiness evaluation is proposed in this paper. This metric belongs to the *no-reference* class of methods as it does not require a comparison with a reference image. Validation tests have been developed in order to assess the index performances when compared with other classical indexes like Hosaka Plots [17], Vlachos index [18] and the Picture Quality Scale (PQS) F_3 factor [19].

JPEG and JPEG2000 test images compressed at the same bitrate, have been analyzed in order to evaluate the distortion selectivity of the proposed metric when applied to DCT-block based coding (JPEG) and Wavelet coding (JPEG2000, not block-based).

2. OVERVIEW OF IMAGE BLOCKINESS ASSESSMENT METHODS

Blockiness is one of the most common distortion effects in block-based compression techniques (e.g. JPEG, MPEGx and H.26x). Several blockiness metrics have been proposed in literature. A brief overview of some quality metrics is presented in this section.

2.1. Full-Reference methods

A full-reference method for assessing image quality quantifies the differences between a distorted image and a reference image. The main approaches proposed in literature are based on the sensitivity of the human visual system (HVS), on filter operators, on a combination of multiple features. Other approaches are not numerical but based on a graphical representation of the image quality. Blockiness distortion indexes are often integrated in a more general global distortion assessment metric.

A full-reference metric [19], called Picture Quality Scale (PQS) combines five factors, which respectively and

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selectively assess five different noise effects. The third factor, called F_3, represents the blockiness evaluation component.

The Hosaka plot [17] is a graphical quality index. Since human eyes perceive the distortion effects in a different manner depending on the amount of local variations within the image signal, the image plane is divided into several, coherent regions. Local standard deviation and mean are computed in the degraded image and compared with the corresponding measures in the original image. Values are plotted in polar coordinates. The area and shape of the Hosaka plot give information about the type and amount of degradation.

2.2. No-reference blockiness evaluation methods

A *no-reference* method quantifies the quality of an image without examining the reference one.

The no-reference method proposed in [3] considers the image signal as the superimposition of a clean information signal with a noise signal resulting from the block-based compression. The blockiness measurement is obtained from the detection and evaluation of the power of the blocky signal.

A no-reference DCT-domain method for blind measurement of blocking artifacts was presented in [4]. The method models the artifacts as two-dimensional step functions in shifted blocks.

A no-reference global quality index was presented in [8]. The algorithm is based on a HVS model and on the union of several factors that represent a measure of the single distortion effects. The blockiness index is based on differences between pixel values across the block boundaries.

Vlachos [18] proposed a no-reference algorithm based on the cross-correlation of subsampled images. Eight sub-images, containing a set of given pixel, are constructed. Then, the cross-correlation between different couple of the sub-images is computed. A measure of blockiness is obtained from a functional depending on the cross-correlations. A drawback of this metric is the high computational complexity.

3. A NOVEL SOBEL-BASED BLOCKINESS INDEX

A convolution is performed between an image I and two Sobel masks M_x and M_y defined as follows:

$$M_x = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}, M_y = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}. \qquad (1)$$

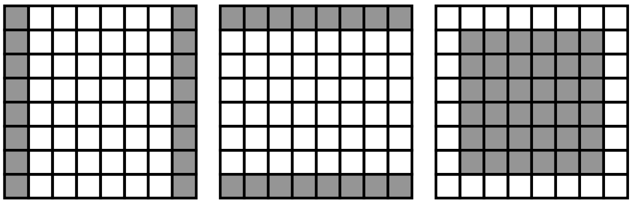


Fig. 1. Gray elements defining the sets Ω_{1V} (left), Ω_{1H} (centre) and Ω_2 (right) in a $N \times N$ block (N=8).

The image convolutions are denoted as

$$\begin{aligned} D_x &= I * M_x \\ D_y &= I * M_y \end{aligned} \qquad (2)$$

where * is the convolution operator.

D_x and D_y are decomposed into $N \times N$ nonoverlapping blocks ($N = 8$, for assessing blockiness artifacts caused by 8 x 8 DCT transform as in JPEG compression).

The sets Ω_{1V}, Ω_{1H}, Ω_2 (Fig. 1) are considered for each $N \times N$ block. Ω_{1V} denotes the pixels of the vertical boundaries between adjacent blocks, Ω_{1H} denotes the pixels of the horizontal boundaries and Ω_2 denotes the inner pixels.

The following measures are defined:

$$s_1 = \frac{1}{N_1}\left(\sum_{(i,j)\in\Omega_{1V}} \frac{|D_x(i,j)|}{\max(D_x)} + \sum_{(i,j)\in\Omega_{1H}} \frac{|D_y(i,j)|}{\max(D_y)} \right) \qquad (3)$$

$$s_2 = \frac{1}{N_2} \sum_{(i,j)\in\Omega_2} \frac{D(i,j)}{\max(D)} \qquad (4)$$

where $D(i,j) = \sqrt{D_x(i,j)^2 + D_y(i,j)^2}$, s_1 is a measure of the boundary block edges, and s_2 is a measure of the inner block edges, N_1 and N_2 are two normalization factors (N_1 and N_2 are the number of elements in the sums (3) and (4), respectively).

The proposed global blockiness measure is defined as follows:

$$S = \left| \frac{s_1^{\lambda} - s_2^{\lambda}}{s_1^{\lambda} + s_2^{\lambda}} \right| \qquad (5)$$

The exponent λ is useful for controlling the slope of the index S, in order to adjust the proposed blockiness measure with human perception tests.

The exponent λ, that maximized the correlation with subjective evaluation, was determined experimentally ($\lambda = 2$). The range of S is [0,1] where zero corresponds to the absence of blockiness distortion while one corresponds to an image severely affected by blockiness distortion.

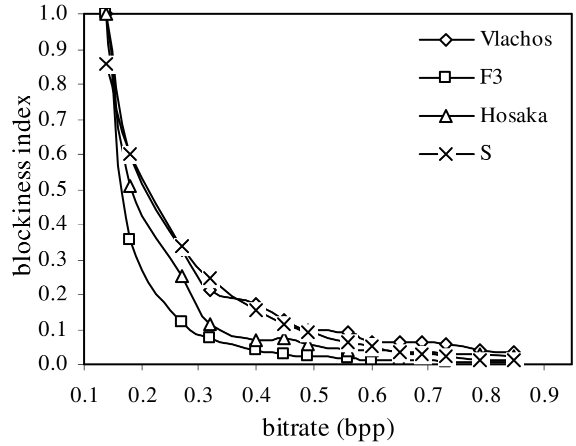
4. EXPERIMENTAL TESTS AND RESULTS

The proposed *no-reference* metric has been compared with Hosaka plot [17], PQS F_3 [19] and Vlachos [18]. A numerical measure of the Hosaka plot is computed as the sum of the plot areas. Three validation tests have been performed in order to assess the effectiveness of the proposed blockiness index. In the first test, the sensibility to the JPEG blockiness distortion is evaluated using several gray-level images compressed at different bitrates. The results, reported in Fig. 2(a) for Lena image, show that the proposed index has the property of monotonicity like the other indexes. In particular, the two no-reference metrics S and Vlachos are very similar to the two reference metrics Hosaka and F_3. Moreover, the proposed S metric has low computational complexity compared to Vlachos cross-correlation based algorithm.

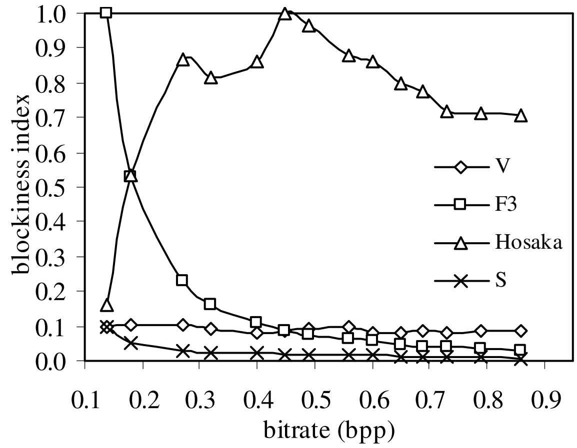
A second test was performed corrupting the test images with six different types of distortion (blurring, Gaussian noise, salt and pepper noise, shifting, contrast stretching and speckle) in order to evaluate the index dependence from each of these distortions. The results of the second validation test are presented in Table 1. It can be noted that the proposed measure presents the desirable independence from all the tested noise effects.

A third validation test was performed for analyzing the independence of the proposed index from the wavelet-based JPEG2000 encoding method. Several test images were encoded with the same increasing compression ratio for both JPEG and JPEG2000 standards. It is well known that JPEG2000 coded images do not present blockiness distortion. For this reason, a reliable blockiness measure should have the property of being very close to zero when applied to JPEG2000 images. In Fig. 2(b), it can be noted that both the Hosaka index and PQS F_3 indexes do not have this property, in particular at high compression ratios. Furthermore, it can be noted the independence of the proposed S index and of the Vlachos index from the JPEG2000 compression. In these cases, the index graphs are nearly horizontal lines with a value that is almost zero, when applied to JPEG2000 images.

Fig. 3 shows a tile of Lena image coded at different bitrates and the corresponding S index.



(a) Lena JPEG-coded



(b) Lena JPEG2000-coded

Fig. 2. Normalized Vlachos, Hosaka and F_3 indexes compared with S index. Several test images compressed at different bpp are evaluated (images are compressed with JPEG (a) and JPEG2000 (b)). Analysis on JPEG compressed images (a) show that blockiness indexes decrease when bit per pixels increase. Instead, it can be noted the independence of the proposed index from the JPEG2000 compression (b).

(a) (b)

Fig. 3. A tile of Lena image compressed at 0.5bpp (a) and 0.2bpp (b). Image (a) has a very low (S=0.064) amount of distortion while image (b) has an appreciable amount of blockiness distortion (S=0.540).

Index	Distortions					
	Shift	Blur	Contr	Gauss	Speckle	S&P
Vlachos	0.092	0.135	0.093	0.114	0.096	0.065
F_3	0.009	1.000	0.328	0.292	0.180	0.489
Hosaka	0.000	0.025	0.120	1.000	0.911	0.398
S	0.004	0.028	0.004	0.011	0.008	0.017

Table 1. Normalized Vlachos, Hosaka and F_3 quality indexes compared with *S* index computed on noise-distorted images. *S* is independent ($S \approx 0$) from all distortions.

5. CONCLUSIONS

In this paper, a novel *no-reference* approach for the blockiness evaluation based on the Sobel filter has been proposed. The algorithm achieves good results with a very low complexity algorithm.

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