NO-REFERENCE IMAGE QUALITY ASSESSMENT FOR JPEG/JPEG2000 CODING

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ABSTRACT

This paper presents a no-reference image quality assessment model for JPEG/JPEG2000 coding. This assessment model are based on the blockiness around the block boundary, the average absolute difference between adjacent pixels within block, and the zero-crossing rate within block. The descrimination of JPEG coded image and JPEG2000 coded image is performed using the information of the blockiness and the average absolute difference between adjacent pixels. For image quality assessment of JPEG2000 coding, the blur measure is introduced instead of the blockiness of JPEG coding.

1. INTRODUCTION

In recent years, there has been an increasing need to develop objective measurement techniques that can predict image/video quality automatically. The most widely used objective image quality/distortion metrics are Peak Signal-to-Noise Ratio (PSNR) and Mean Squared Error (MSE), but they are widely criticized as well for not correlating well with perceived quality measurement. In the past, a great deal of effort has been made to develop new objective image/video quality metrics that incorporate perceptual quality measures by considering Human Visual System (HVS) characteristics. Most of the proposed image quality assessment approaches require the original image as a reference.

Interestingly, human observers can easily assess the quality of distorted images without using any reference image. By contrast, designing objective No-Reference (NR) quality measurement algorithms is a very difficult task. This is mainly due to the limited understanding of the HVS, and it is believed that effective NR quality assessment is feasible only when the prior knowledge about the image distortion types is available. Although only several methods have been proposed for objective NR quality assessment [1]-[3], this topic has attracted a great deal of attention recently.

Different coding schemes are characterized by very different types of artifacts. For instance, the coding techniques based on the Discrete Cosine Transform (DCT) of image blocks, such as those used in JPEG and MPEG, mostly bring about blocking artifacts called blockiness. In the JPEG 2000 coding, which is based on a wavelet transform, this class of coding schemes mostly introduces blur and ringing artifacts.

In this paper, we propose a no-reference quality assessment model for JPEG/JPEG2000 coded image. This metric is defined in the spatial domain and based on the measurement of the blockiness for JPEG coded image, and the blur measure for JPEG2000 coded image. The proposed model gives good agreement with subjective MOS score.

2. SUBJECTIVE EXPERIMENT

The subjective test was conducted on 24 bits/pixel color images. There are 98 test images in the database. Fourteen of them are original images. The rest of the test images are JPEG coded images and JPEG2000 coded images. The 6 quality factors are selected randomly for each coder. Fifteen subjects were shown the database; most of them were college students. The subjects were asked to assign each image a quality score between 1 and 5 under the test conditions of ITU-R Rec. 500-10. The 98 scores of each image were averaged to a final Mean Opinion Score (MOS) of the image. In this experiment, the average of 95% confidence interval is 0.33.

3. NR QUALITY ASSESSMENT MODEL OF JPEG CODED IMAGE

JPEG is a block-based DCT lossy image coding technique. It is lossy because of the quantization operation applied to the DCT coefficients in each 8 × 8 coding block. Both blur and blockiness may be created during quantization. The blur is mainly due to the loss of high frequency DCT coefficients, which smoothes the image signal within each block. Blockiness occurs due to the discontinuity at block boundaries, which is generated because the quantization in JPEG is block-based and the blocks are quantized independently.

One effective way to examine both blur and blockiness is to transform the signal into the frequency domain [2]. The blockiness can be easily identified by the peaks at the several feature frequencies and the blur is also characterized by the energy shifting from high frequency to low frequency bands. A disadvantage of the frequency domain method is the involvement of the Fast Fourier Transform (FFT), which has to be calculated many times for each image, and is therefore expensive. FFT also requires more storage space because it cannot be computed locally.

In this paper, we employ a computationally inexpensive and memory efficient feature extraction method for evaluating the JPEG coded image quality [4]. This model is shown in Figure 1. The features are calculated horizontally and then vertically. First, the blockiness is estimated as the average differences across block boundaries:

$$B_h = \frac{1}{M([N/8]-1)} \sum_{i=1}^{M} \sum_{j=1}^{[N/8]-1} |d_h(i, 8j)| \tag{1}$$

where we denote the test image signal as $x(m,n)$ for $m \in [1,M]$ and $n \in [1,N]$, and calculate a differencing signal along each horizontal line:

$$d_h(m,n) = x(m,n+1) - x(m,n), n \in [1, N-1]. \tag{2}$$

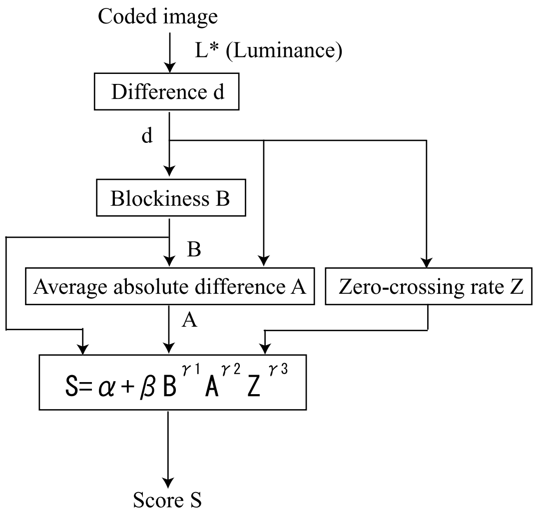

Figure 1: NR quality assessment model.

Second, we estimate the activity of the image signal. Although blur is difficult to be evaluated without the reference image, it causes the reduction of signal activity, and combining the blockiness and activity measures gives more insight into the relative blur in the image. The activity is measured using two factors. The first is the average absolute difference between in-block image samples:

$$A_h = \frac{1}{7}\left[\frac{8}{M(N-1)}\sum_{i=1}^{M}\sum_{j=1}^{N-1}|d_h(i,j)| - B_h\right] \tag{3}$$

The second activity measure is the zero-crossing (ZC) rate. We define for $n \in [1, N-2]$,

$$z_h = \begin{cases} 1 & \text{horizontal ZC at } d_h(m,n) \\ 0 & \text{otherwise} \end{cases} \tag{4}$$

The horizontal ZC rate then can be estimated as:

$$Z_h = \frac{1}{M(N-2)}\sum_{i=1}^{M}\sum_{j=1}^{N-2} z_h(i,j) \tag{5}$$

Using similar methods, we calculate the the vertical features of Bv, Av, and Zv. Finally, the overall features B, A and Z are given by:

$$B = \frac{B_h + B_v}{2}, A = \frac{A_h + A_v}{2}, Z = \frac{Z_h + Z_v}{2} \tag{6}$$

There are many different ways to combine the features to constitute a quality assessment model. One method we find that gives good prediction performance is given by

$$S = \alpha + \beta B^{\gamma_1} A^{\gamma_2} Z^{\gamma_3} \tag{7}$$

where $\alpha, \beta, \gamma_1, \gamma_2$, and γ_3 are the model parameters that must be estimated with the subjective test data such as Mean Opinion Score (MOS). In our experiment, the optimization of model parameters are performed by using the Particle Swarm Optimization (PSO) [5]. This mentioned model is not take into account the nonlinearity between the human perception and the physical feature, so our image quality evaluation model considers the logistic function as the nonlinear property. Finally, obtained assessment score SS is derived from the following equation.

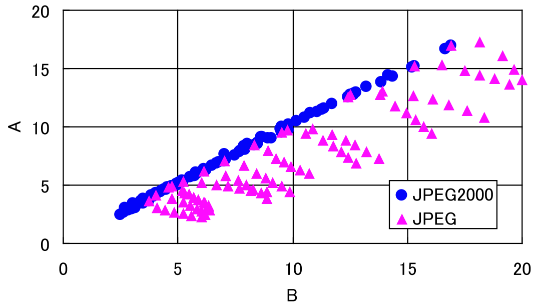

Figure 2: Relation of block noise "B" and absolute difference within blocks "A".

$$SS = \frac{4}{1 + exp(-1.0217(S-3))} + 1 \tag{8}$$

4. AUTOMATIC DISCRIMINATION OF CODED IMAGE

The type of the quality degradation between the JPEG coded image and the JPEG2000 coded image is different. Therefore, it is difficult to evaluate different encoded images by using the image quality evaluation model which uses the same features. From this reason, the automatic discrimination method between the JPEG coded image and the JPEG2000 coded image is examined from several features of previously described image quality evaluation model. By using this discrimination information, the construction of the image quality evaluation model who corresponds to the JPEG coded image and the JPEG2000 coded image is performed, by switching the amount of the feature corresponding to each coded image.

First, from each JPEG/JPEG2000 coded image, by equation (1) (3), the average over the entire image of the blockiness (B) and the average absolute difference between in-block image samples (A) are calculated. The easy discrimination of coded image is performed by comparing these two values. Figures 2 shows the result between (B) and (A) for both JPEG/JPEG2000 coded images. From this figure 2, it becomes $B > A$ in the JPEG coded image. JPEG coder is encoded in the block of 8*8 pixels. As a result, the block noise is caused between adjacent blocks, and it is much bigger than the brightness difference between adjacent pixels within block. On the other hand, for the JPEG2000 coded image, $B = A$ is understood. Consequently, if $B = A$, it is JPEG coded image, and in case of $B > A$, it is possible to distinguish as the JPEG2000 coded image. When we attempted to use this method under our research environment, it was possible to distinguish accurately regardless of the compressibility.

5. NR BLUR METRIC OF JPEG2000 CODED IMAGE

Blur in an image is due to the attenuation of the high spatial frequency coefficients in its spectrum, which commonly occurs during visual data compression. In the JPEG 2000 lossy compression scheme, the standard filter used in the wavelet decomposition is the Daubechies (9, 7). Therefore, this coding schemes mostly introduces blur and ringing artifacts. The blur and ringing metrics may be defined in the spatial domain. Both artifacts appear mostly along edges or in textured areas. The blur metric thus attempts to measure the spread of the edges, whereas the ringing metric measures the ripples or oscillations around these edges. For color images, blur and ringing are measured on the luminance component.

A no-reference blur measurement technique has been already proposed [6]. This measurement assume no knowledge of the original image, and do not make any assumptions on the type of content or the blurring process. The result is an objective measure which correlates with the perception of blur. The blur measurement is defined in the spatial domain. Blur is perceptually apparent along edges or in textured areas. This technique is based on the smoothing effect of blur on edges, and consequently attempts to measure the spread of the edges.

Our technique for measuring blur is based on the smoothing or smearing effect of compression on sharp edges, and consequently attempts to measure the spread of the edges. First, we apply a Sobel filter to the luminance component of the image in order to find significant edges in the image. Then, it scan each row of the processed image. For pixels corresponding to an edge location, the start and end positions of the edge are defined as the locations of the local luminance extrema closest to the edge. The spread of the edge is then given by the distance between the end and start positions, and is identified as the local blur measure for this edge location. The global blur measure for the whole image is obtained by averaging the local blur values over all edges found.

6. NEW NR QUALITY ASSESSMENT MODEL OF JPEG/JPEG2000 CODED IMAGE

In this section, we propose a new no-reference quality assessment model for JPEG/JPEGE2000 coded image. The image quality is evaluated by distinguishing the JPEG coded image and the JPEG2000 coded image by the above-mentioned automatic discrimination method, and switching the amount of the feature of each coded image of the image quality evaluation model. For JPEG coded image, an existing image quality evaluation model is handled. Moreover, for JPEG2000 coded image, because the block noise is not generated in the JPEG2000 encoding, the blur measure is used as an amount of the feature instead of the blockiness. Figure 3 shows our image quality evaluation model. Here, the parameter becomes seven for JPEG2000 coded image.

7. RESULTS

Figure 4 shows the result of our image quality evaluation model of figure 3. For the comparison of the existing image quality evaluation model, the result which is not distinguishing the coded images is also shown in figure 5. Our proposed model performs well under our subjective data. In addition, the result of each JPEG and JPEG2000 coded image is shown in figure 6 and figure 7, and the estimation accuracy is shown in table 1. From figure 4 and figure 5, it is clear that the estimation accuracy has improved by distinguishing the coded image and switching the amount of the feature. Moreover, for the comparison of the estimation accuracy of the JPEG coded image and the JPEG2000 coded image from figure 6 and figure 7, our model gives good agreement with MOS for the JPEG coded image though a insufficient result was obtained in the JPEG2000 coded image.

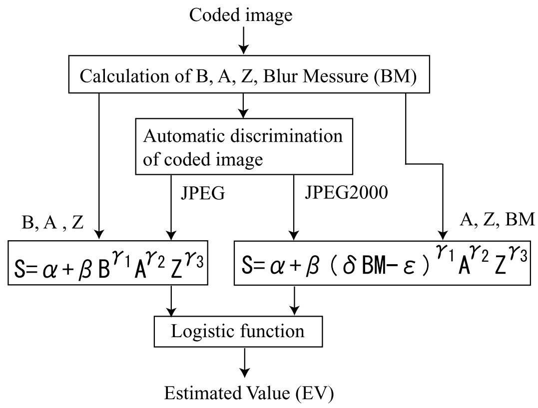

Figure 3: New NR quality assessment model.

Table 1: Estimation accuracy.

Model	Corr.	Ave.	Max.
No discrimination (JPEG, JPEG2000)	0.68	1.00	1.77
Proposed (JPEG, JPEG2000)	0.89	0.50	1.43
Proposed (JPEG only)	0.94	0.37	0.92
Proposed (JPEG2000 only)	0.82	0.62	1.43

8. CONCLUSIONS

We propose a no-reference quality assessment model for JPEG/JPEG2000 coded image. This model is based on the measurement of the blockiness for JPEG coded image, and the blur measure for JPEG2000 coded image. By using the relation between the blockiness across block boundary and the average absolute difference between in-block pixels, we can obtain a novel automatic discrimination method of coded image. The proposed model gives good agreement with MOS score. The advantage of this model is low computational complexity and the performance is independent of the image content. Future research includes the introduction of other type of JPEG2000 artifacts such as ringing.

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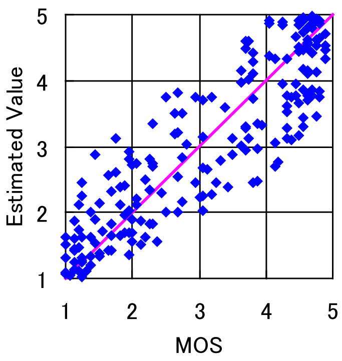

Figure 4: Evaluation result using automatic discrimination (proposed model).

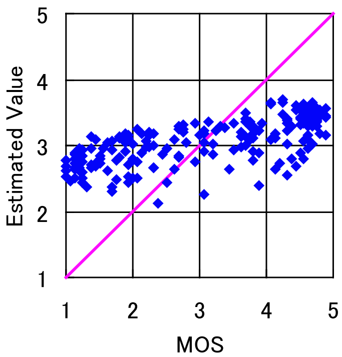

Figure 5: Evaluation result without using automatic discrimination.

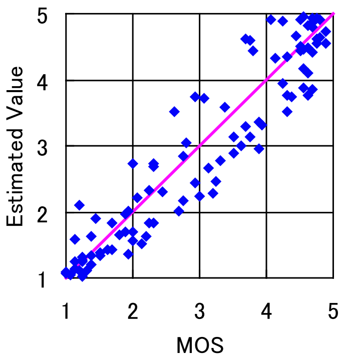

Figure 6: Evaluation result using automatic discrimination (JPEG coded image)

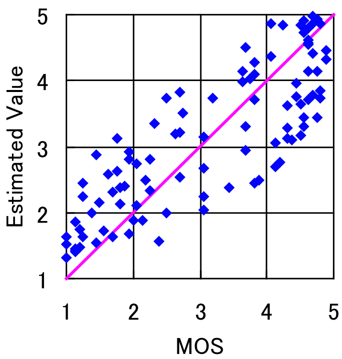

Figure 7: Evaluation result using automatic discrimination (JPEG2000 codec image)

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