

QUALITY EVALUATION MODEL USING LOCAL FEATURES OF STILL PICTURE

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ABSTRACT

The objective image quality evaluation model for coded image without using the reference is very useful for quality oriented image compression. In this paper, a new objective no-reference (NR) image quality evaluation model for JPEG coded image is presented, which is easy to calculate and applicable to various image processing applications. The proposed model is based on the local features information of the image such as edge, flat and texture area and also on the blockiness, activity measures, and zero crossing rate within block of the image. Our experiments on various image distortion types indicate that it performs significantly better than the conventional model.

1. INTRODUCTION

It is ever increasing requirement to send more multimedia data over tighter bandwidth which has driven to develop advanced compression technology. Obviously, digital images suffer a wide variety of distortion in many image processing applications from compression to printing. Because of these, perceptual quality of the images are degraded. Therefore image quality measurement is a important problem in many image processing applications. There is no doubt that subjective image quality evaluation is perfect and well recognised method. Though the subjective test is considered to be the most accurate method since it reflects human perception, it is time consuming and expensive. Furthermore, it cannot be done in real time. As a result, there has been a great interest in developing objective image quality evaluation methods. Objective image quality metrics can be classified into three way, full reference(FR), reduced reference(RR) and no reference(NR). In full reference quality assessment, a "reference" image of perfect quality is used to predict the quality of the degraded image. Some extracted features of original image are used to evaluate the quality of the degraded image in reduced reference quality assessment. In case of no reference quality assessment, no need any reference image to evaluate the quality of any degraded images. In many applications, reference signal is not available and also may be too expensive to provide it. As a result, no reference quality evaluation has got a great attention to all related researchers recently.

Peak Signal-to-Noise Ratio (PSNR) and Mean Squared Error (MSE) are the most widely used objective image quality metrics, but they are not well correlated with perceived quality measurement and widely criticized. Good amount of researches have already been done to develop new objective image quality metric by considering Human Visual System(HVS) characteristics [1]-[4]. A full reference (FR) objective perceptual video quality measurement techniques

for digital cable television is proposed based on segmentation algorithm in [5].

As block-based video and image compression algorithm is very popular for image and video coding and transmission. Blind measurement of blocking artifact has been the main emphasis of no reference quality assessment research in [6]-[11]. In these reference, most blocking measurement is quantified either in the frequency domain or in the spatial domain. In [12], an NR image quality assessment model for JPEG is proposed, which is based on blockiness and average activity measure of the image. Though the algorithms is very interesting, it's used only gray level MOS score. In [13], an NR blur metric is proposed, which is based on the analysis of the spread of the edges in an image. But it's studied on the limited number of compressed image.

In this paper, we propose a new objective no-reference (NR) image quality evaluation model for JPEG based on the local features information of the image such as edge, flat and texture area and also on the blockiness, activity measures, and zero crossing rate within block of the image. The metrics are defined in the spatial domain and based on the measurement of blockiness and blurring. The proposed model gives good agreement with subjective MOS score.

2. SUBJECTIVE EXPERIMENTS

The subjective experiments were conducted on 24 bit/pixel RGB color images. In these experiments, a number of human subjects were asked to assign each image with a score indicating their assessment of the quality of that image, defined as the extent to which the artifacts were visible. There were 98 images of size 768×512 in the database for JPEG. Fourteen of it were original images. The rest of the images were JPEG coded images. The six quality scales, 15, 20, 27, 37, 55 and 79 were selected for JPEG encoder [15]. All subjects were screened prior to participate the session for normal 20/20 visual acuity with or without glasses, normal color vision and familiarity with the language. Fifteen non-expert subjects were shown the database, most of them were college student. The subjects were asked to provide their perception of quality on a discrete quality score that was divided into five and marked with the numerical value of adjectives "Bad=1", "Poor=2", "Fair=3", "Good=4" and "Excellent=5" under the test conditions of ITU-R Rec. 500-10 [14]. The fifteen scores of each image were averaged to get a final Mean Opinion Score (MOS) of the image with subject reliability of 95% confidence interval.

3. CONVENTIONAL IMAGE QUALITY EVALUATION MODEL

One of the important compression algorithms is the lossy JPEG image compression standard, which is based on the block-based discrete cosine transform (DCT). During quantization of the DCT coefficient, blocking and blurring artifacts are produced. In this research, the proposed mathematical measures are extracted features which are calculated in spatial domain. As 8×8 is a common block size in JPEG compression and other image processing applications the block size used in our measures is 8×8 . The extracted features measure is blockiness, activity and zero crossing rate measure within block of the image [12]. The features are calculated horizontally and then vertically. The block diagram of the conventional NR model is shown in Figure 1. For all calculations, we consider only luminance component Y of color image.

Blockiness measure in horizontal direction:

It's the average differences across block boundaries

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

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:

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

Without reference image, it's very difficult to measure blur within a image. It's mainly the cause of signal activity in the image. Combining the features (blockiness, activity measures and zero crossing rate) may gives more insight into the relative blur in the image.

Activity measure in horizontal direction:

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

Zero-crossing (ZC) rate measurement:

For horizontal ZC rate:

$$d_{h-sign}(m, n) = \begin{cases} 1 & \text{if } d_h(m, n) > 0 \\ -1 & \text{if } d_h(m, n) < 0 \\ 0 & \text{otherwise} \end{cases} \quad (4)$$

$$\begin{aligned} d_{h-mul}(m, n) \\ = d_{h-sign}(m, n) \cdot d_{h-sign}(m, n+1) \end{aligned} \quad (5)$$

$$z_h(m, n) = \begin{cases} 1 & \text{if } d_{h-mul}(m, n) < 0 \\ 0 & \text{otherwise} \end{cases} \quad (6)$$

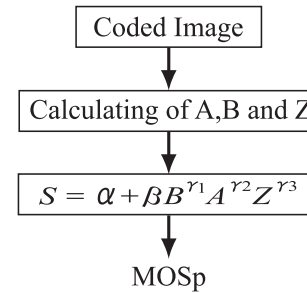


Figure 1: Conventional NR quality evaluation model [12].

The horizontal ZC rate then can be estimated as:

$$Z_h = \frac{1}{M(N-2)} \sum_{i=1}^M \sum_{j=1}^{N-2} z_h(i, j) \quad (7)$$

Similarly we calculate the vertical features of B_v , A_v , and Z_v . So, the overall features B, A and Z per image are given by:

$$B = \frac{B_h + B_v}{2}, A = \frac{A_h + A_v}{2}, Z = \frac{Z_h + Z_v}{2} \quad (8)$$

The features are combined by the following equation (9). This is the quality assessment model's equation.

$$S = \alpha + \beta A^{\gamma_1} B^{\gamma_2} Z^{\gamma_3} \quad (9)$$

The model parameters are α , β , γ_1 , γ_2 , and γ_3 that must be estimated with the subjective test data such as Mean Opinion Score(MOS).

4. PROPOSED IMAGE QUALITY EVALUATION MODEL BASED ON THE SEGMENTATION ALGORITHM

The perceived image distortion is strongly depend on the local features of the image, such as edge, flat and texture. Therefore the perceived differences between the local features should apply for the development of the objective quality evaluation model. In our proposed model, the mathematical measures are local and extracted features which are calculated in spatial domain. In this research, we have updated the blockiness value B, the activity measure A and the zero-crossing Z using a new block based segmentation algorithm. The proposed model is shown in Figure 2.

Firstly, we use the CPqD segmentation algorithm to classify each pixel within the image into either edge, texture or flat pixel (CPqD) [5]. Initially, the segmentation algorithm classifies each pixel in the component Y of the image into plane and non-plane regions. The algorithm also applies to Y, an edge detector and the edge regions are defined by edges that fall within the boundary of the plane regions. The texture regions are composed by the remaining pixels of the image Y.

Secondly, we have classified each block (8×8) of the image into either edge, texture or flat block by using our new segmentation algorithm and then calculated the blockiness, activity measure and zero crossing rate of the block.

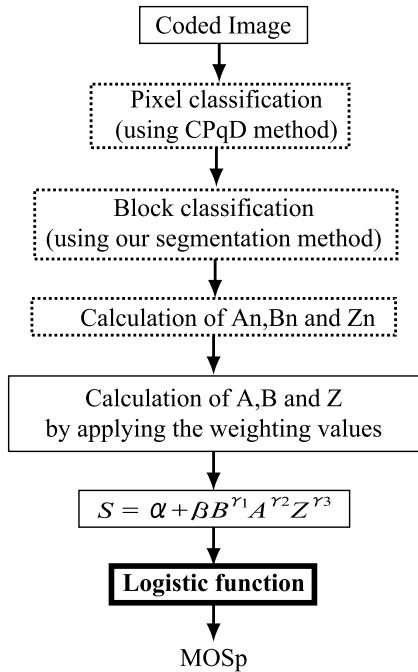


Figure 2: Proposed NR quality evaluation model.

The new block based segmentation algorithm:

$$Sum = n_e + n_t + n_f \quad (10)$$

where n_e , n_t , and n_f are respectively the number of edge, texture and flat pixels per (8×8) block within the image. Therefore, the "Sum" is the total number of pixels per block.

if $\left(\frac{n_e}{Sum} > th_e\right)$ then the block is "edge"
 else if $\left(\frac{n_f}{Sum - n_e} > th_f\right)$ then the block is "flat"
 else the block is "texture"

The threshold values, th_e and th_f are used in the segmentation algorithm are calculated by PSO optimization method [16].

Thirdly, using the new segmentation algorithm we have classified each block (8×8) of the image into either edge, texture or flat block and then calculated the blockiness, activity measure and zero crossing rate of these block. The total blockiness value of edge, texture and flat blocks are calculated by

$$B_e = \frac{1}{N_e} \sum_{n=1}^{N_e} B_{en} \quad (11)$$

$$B_t = \frac{1}{N_t} \sum_{n=1}^{N_t} B_{tn} \quad (12)$$

$$B_f = \frac{1}{N_f} \sum_{n=1}^{N_f} B_{fn} \quad (13)$$

where B_e , B_t , and B_f are respectively the total blockiness value of edge, texture and flat blocks of the image. Similarly

we calculate the total activity measure and zero-crossing rate of edge, texture and flat blocks of the image. That is the value of A_e , A_t , A_f , Z_e , Z_t , and Z_f . N is the number of the corresponding blocks and the subscript e, t and f respectively indicate the edge, texture and flat. Finally the blockiness, activity measure and zero-crossing rate of each image are calculated by

$$B = W_{be} \cdot B_e + W_{bt} \cdot B_t + W_{bf} \cdot B_f \quad (14)$$

$$A = W_{ae} \cdot A_e + W_{at} \cdot A_t + W_{af} \cdot A_f \quad (15)$$

$$Z = W_{ze} \cdot Z_e + W_{zt} \cdot Z_t + W_{zf} \cdot Z_f \quad (16)$$

where W_{be} , W_{bt} , and W_{bf} are the weight factors for edge, texture and flat blocks of blockiness and similarly W_{ae} , W_{at} , and W_{af} for activity measure and also W_{ze} , W_{zt} , and W_{zf} are the weight factors for zero-crossing rate. The features are combined by the same equation (9) that was used in Wang's model [12]. This mentioned model is not taken into account the nonlinearity between the human perception and the physical feature, so our quality evaluation model considers the logistic function as the nonlinear property.

Finally, obtained evaluation score MOS_p is derived from the following equation.

$$MOS_p = \frac{4}{1 + \exp[-1.0217(S - 3)]} + 1 \quad (17)$$

5. RESULTS

The optimization of model parameters and the weight factors are performed by using the Particle Swarm Optimization(PSO) algorithm[16]. The parameters obtained with all images are $\alpha = 4.99897$, $\beta = -1.23528$, $\gamma_1 = 3.55996$, $\gamma_2 = -2.97072$, and $\gamma_3 = -0.65452$. The value of weighting factors are $W_{be} = 2.82721$, $W_{bt} = -3.49716$, $W_{bf} = 136.043$, $W_{ae} = 27.5951$, $W_{at} = -33.0126$, $W_{af} = 156.696$, $W_{ze} = 68.2039$, $W_{zt} = 10.538$ and $W_{zf} = 28.9901$.

One original image and its CPqD segmented image are shown in Figure 3 and 4. The edge, texture and flat pixels are respectively look like black, light black and gray in the CPqD segmented image. The CPqD segmented JPEG coded image of the same original image is shown in Figure 5. And also our new segmentation algorithm based segmented JPEG code image of the same image is shown in Figure 6. The edge, texture and flat blocks are respectively look like black, light black and gray in our block based segmented image. The threshold values, th_e and th_f in our proposed segmentation algorithm are same and the value is 0.3 which are calculated by PSO optimization method [16].

The conventional Wang's model and our model's estimation accuracy based on our database are shown in Table 1. As a comparison, we can compare the performance of our model against the conventional model[12]. In this case, we have calculated correlation coefficient, average error and maximum error. The correlation coefficient, average error and maximum error of the conventional model are respectively 0.87,



Figure 3: Original image.



Figure 4: CPqD segmented image (Original).

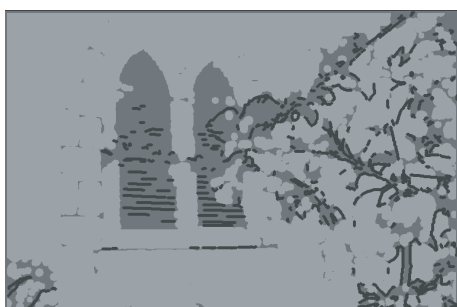


Figure 5: CPqD segmented image (JPEG).

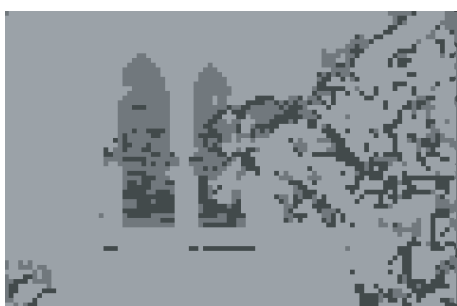


Figure 6: Proposed segmented image (JPEG).

0.56 and 1.31. But on the same database, we obtain the correlation coefficient, average error and maximum error of our proposed model are respectively 0.97, 0.28 and 0.67. Therefore performance of our model all double times better compare to the conventional model. The conventional Wang's model performance without and with logistic function are respectively shown in Figure 7 and 8. The performance of our proposed model without and with logistic function are also respectively shown in Figure 9 and 10.

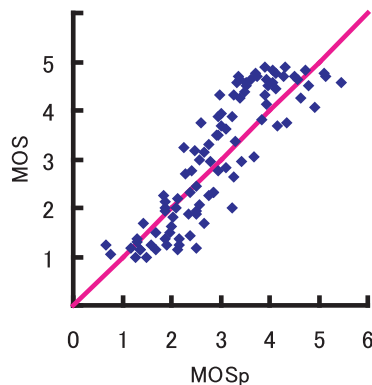


Figure 7: MOS prediction results of Wang's model without logistic function.

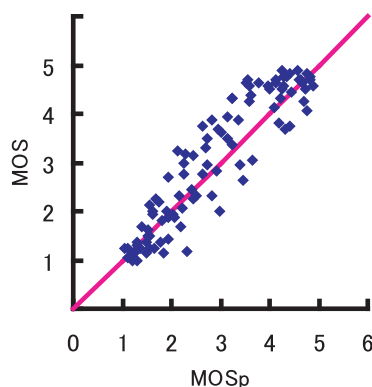


Figure 8: MOS prediction results of Wang's model with logistic function.

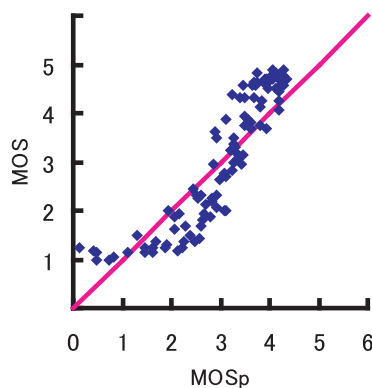


Figure 9: MOS prediction results of the Proposed model without logistic function.

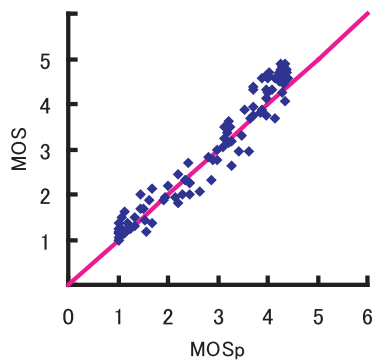


Figure 10: MOS prediction results of the Proposed model with logistic function.

Table 1: Models' estimated accuracy based on our database.

Model	Corr.	Ave.	Max.
Wang model	0.87	0.56	1.31
Wang model with logistic function	0.92	0.42	1.12
Proposed model without logistic function	0.90	0.53	1.13
Proposed model with logistic function	0.97	0.28	0.67

6. CONCLUSIONS

A new image quality evaluation model for JPEG coded image has been presented in this paper. The proposed model is based on the local features information of the image such as edge, flat and texture area and also on the blockiness, activity measures, and zero-crossing rate within block of the image. The model's performance on various distortion types image is more better compare to the conventional Wang's model. The proposed model has given good agreement with MOS. The advantages of this model is low computational complexity. In order to improve the proposed model, future research need to consider all three component of color image and also have to develop the suitable combine function.

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