Blockiness Estimation in Reduced Reference Mode for Image Quality Assessment

Muhammad Tahir Qadri, M. Ghanbari

Abstract— **In this paper we present blockiness estimation meter in reduced reference mode using frequency domain analysis. Since blockiness is an abrupt luminance discontinuity at the DCT block boundaries and also has periodic patterns, therefore blockiness generates harmonics in frequency domain. In order to design the quality meter in reduced reference mode, we used the strength of harmonics (of reference image) as reduced reference parameter and compared it with the harmonics of the coded image to estimate blockiness distortion. The severity of blockiness artifact depends upon the strength of harmonics generated in the coded image. The spatial masking is also applied in order to mask the distortion according to the local spatial activity of the image. As the distortion is content specific therefore it is calculated locally for each part of the image by applying block processing technique. To avoid misinterpreting the natural edges lying at the DCT block boundaries, we also applied the edge cancellation process which distinguishes the natural edges and the edges due to blockiness in the coded image. Finally the designed algorithm is tested on the LIVE image database which consists of 233 colored images compressed at different compression rates and when tested with the database, the correlation coefficient of 93.59% is achieved in reduced reference mode.**

Index Terms: Blockiness estimation, reduced reference, frequency domain analysis, image quality estimation.

I. INTRODUCTION

In order to utilize the limited bandwidth of the spectrum efficiently, we need to compress the images and video sequences. For this purpose, many codecs are used to compress images and video sequences which normally introduce distortions in the coded versions, generally named as artefacts [1]. The most common distortion for images and video sequences is the 'Blockiness' artefact [2-5] which is due to the discontinuities in luminance levels at the discrete cosine transform (DCT) block boundaries. The blockiness is generally not calculated by standard methods of signal processing like filtering or denoising.

Briefly discussing, Blockiness results in spatial domain due to coarsely quantization of pixel values of each DCT block. Blockiness create discontinuities in luminance value at the boundaries of each DCT block and is generally detected by determining the horizontal and vertical abrupt luminance changes at the boundaries of DCT block in the coded image or video.

In order to determine the objective quality of the coded image or video after compression process, an Image Quality Meter (IQM) is required which can estimate the objective quality of the coded image accurately when compared with the user's predictive Mean Opinion Scores (MOS). The most commonly available image Quality Meter is the Peak Signal to Noise Ratio (PSNR) [6] but it has very less correlation with the user's predictive scores i.e. MOS. The behavior of human eye is more sensitive at lower spatial frequencies than the high frequency values [4], so in order to improve the performance of the objective IQM meter, we must include the effect of Human Visual System (HVS). Another issue is that, most of the existing image quality meters [8-11] works in spatial domain to evaluate the quality. The spatial domain techniques include complex calculations and hence they require more time to process the algorithm. These models also require training images set in order to train the model while our proposed method doesn't require any training data set which is another important aspect of this proposed method.

This research proposes a Reduced Reference (RR) quality meter for measuring the blockiness distortion. In RR quality meter, instead of the complete reference image, some information of the reference picture is available at receiver end to quantify the image quality.

It is understandable that the quality of the RR meter is not as good as for full reference approach but in many scenarios, it is not possible to have the full reference information to be available at the user end. The work is implemented by transmitting the reduced reference parameter to the user end and compares it with the coded image's parameter to predict the image quality. The designed algorithm is tested on 233 differently coded images of LIVE image database [12] and the result shows 93.59% correlation even without the use of training images set.

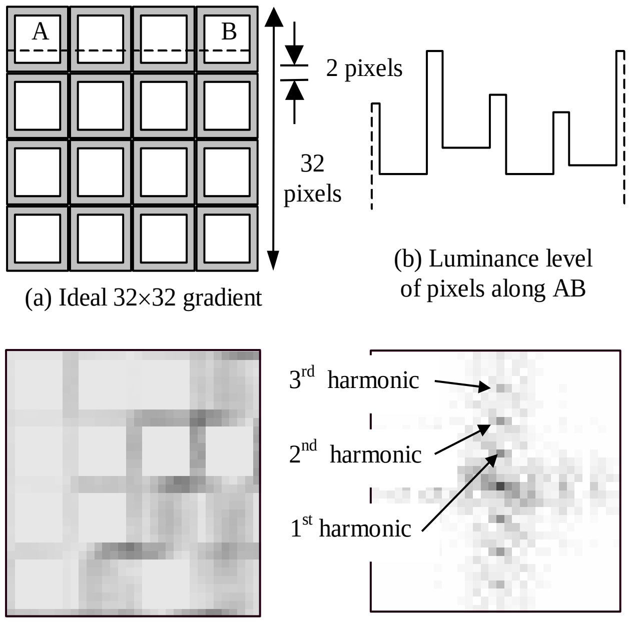
The organization of the paper is as follows: section II provides an overview of blockiness distortion estimation using frequency domain analysis. Section III explains the proposed reduced reference Image Quality meter. Section IV is for the calculation of blockiness index and the last section concludes the paper followed by the key references.

II. BLOCKINESS ESTIMATION IN FREQUENCY DOMAIN

Blockiness artifact is the luminance discontinuities across DCT block boundaries. It results due to the course quantization of the DCT coefficients during the process of compression. Since the DCT block size is fixed i.e. 8x8, therefore blockiness has a periodic pattern and it appears at every 8th horizontal and vertical pixels. We estimated the blockiness distortion by transforming the image into frequency domain. The periodic patterns of the blockiness distortion generate harmonics in frequency domain. The severity of the harmonics generated is directly proportional

Muhammad Tahir Qadri, Electronic Engineering Department, Sir Syed University of Engineering and Technology, Karachi, Pakistan, M. Ghanbari, School of Computer Science and Electronic Engineering University of Essex, UK. Email: mtahirq@hotmail.com. Manuscript received May 02, 2014; revised August 29, 2014 and October 07, 2014.

 ISSN – 1999-4974



(a) Ideal 32×32 gradient (b) Luminance level of pixels along AB

(c) Actual 32×32 gradient (d) Fourier Transform

Fig. 1. Basic concept of Harmonic Analysis [2]

to the amount of blockiness distortion. Figure 1 shows the basic concept of harmonics analysis in frequency domain, explained in our previous work in [2-4].Figure 1(a) is an ideal blocky gradient image of 32x32 pixels in spatial domain while figure 1(b) is the luminance level transitions across first row. Figure 1(c) is the gradient of actual blocky image and figure 1(d) is its 2D Fourier transformation. The center sample in figure 1d is the DC value which can be ignored as it only represents the average luminance of the image while other horizontal and vertical coefficient are significant for blockiness estimation. We used the strength of horizontal and vertical harmonics in order to estimate the amount of blockiness distortion. The next section explains the proposed blockiness meter in reduced reference mode.

III. Proposed Reduced Reference Image Quality Meter

The proposed quality meter is divided into 4 parts. The first part is the edge detection process. The second part is the spatial masking process which is applied to mask the distortion. The third part is the block processing in order to calculate the distortion locally. The fourth part is the calculation of the reduced reference parameter using frequency domain analysis. The complete block diagram of the proposed model is illustrated in figure 2.

A. Edge Detection

The first step is the edge detection process which is applied to determine the sharp luminance edges in an image. The edge detection is carried out using vertical and horizontal sobel edge detectors. The edge detection on reference image is applied at transmitter end while on coded image; it is applied on receiver end as explained in the block diagram above.

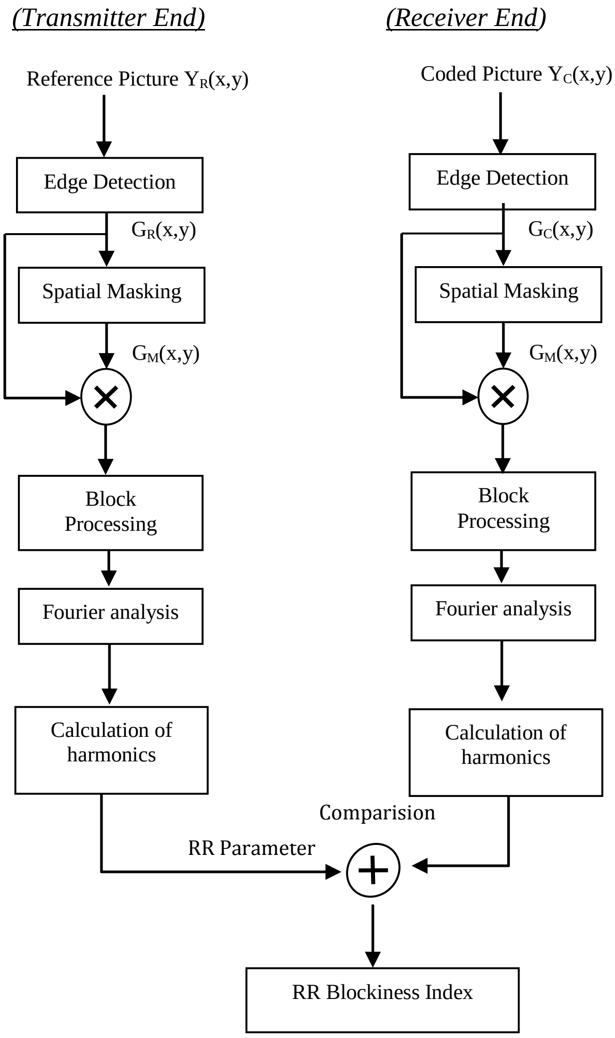


Fig. 2. Block Diagram of the proposed model

B. Spatial Masking in Reduced Reference Mode

The spatial masking is performed because perception of blockiness in detailed areas can be more masked than in low detailed areas of the picture. In order to mask the distortion in reference or coded image, first we determined the spatial activity of that image by obtaining its global masking function.

To derive the global masking function, the edge detected version of the image is used. For each pixel in the edge detected image, a local masking function is derived by considering the impact of 5 neighboring pixels as explained in [10]. Then these local masking functions are used to obtain the global masking function, which contains the spatial activity of the reference image. In this work, the Fiorentini and Zoli's spatial masking from [14] is adopted. The masked reference and coded images are then multiplied by the edge detected reference and coded images respectively so that the distortion is adjusted according to the local spatial activity of the images. The masking process of the reference image is applied at transmitter end while the masking of the coded is performed at the receiver side as illustrated in figure 2. The next step is the block processing of both masked images.

C. Block Processing

Due to the different types of contextual details present in any natural image, there is a possibility that blockiness distortion is not uniform in all parts of the coded image. For this reason the blockiness distortion is calculated locally for each part in the masked image by applying block processing technique in which we divided the image into blocks of pixels in spatial domain and then calculate the distortion locally for each block. We selected the block size of 32x32 pixels as it has to be any multiple of 8x8 because of the fixed DCT block size. If we had chosen 16x16 block size, then there will be only two harmonics due to blockiness and they will not be much apart from each other. Therefore we chose 32x32 pixels block size in which there will be three harmonics (4th, 8th and 12th ac coefficients) and they will be relatively apart from each other in order to distinguish them. After transforming each block of masked reference and masked coded images into blocks of 32x32 pixels in spatial domain, the next step is to calculate the reduced reference parameter from the masked reference image as discussed below.

D. Calculation of Reduced Reference Parameter using Frequency Domain Analysis

In order to determine the reduced reference parameter from the reference image, each block of the masked reference image is transformed into frequency domain by applying 2D Fourier transformation. Since, blockiness has periodic patterns which are represented by harmonics in frequency domain, therefore the strength of ac coefficients at harmonics frequency i.e. 4th, 8th and 12th ac coefficients (vertical and horizontal) of each block in frequency domain are used as reduced reference parameter and compared with the corresponding parameter of the coded image. The equation which is used to determine the reduced reference parameter is explained below.

$$\mathrm{R_{ref}} = \sum(\mathrm{H_4} + \mathrm{H_8} + \mathrm{H_{12}} + \mathrm{V_4} + \mathrm{V_8} + \mathrm{V_{12}})_{\mathrm{reference}} \quad (1)$$

Where, $\mathrm{H_4}$, $\mathrm{H_8}, \mathrm{H_{12}}, \mathrm{V_4}, \mathrm{V_8}$ and $\mathrm{V_{12}}$ are the 4th, 8th and 12th horizontal and vertical harmonics of the reference image respectively.

The next part explains the blockiness index measurement in reduced reference mode.

IV. Blockiness Measurement in Reduced Reference Mode

The reduced reference parameter $\mathrm{R_{ref}}$ is transmitted to the receiver end in order to compare it with the coded parameter to estimate the amount of blockiness distortion. The parameter for coded image is calculated in equation 2 below.

$$\mathrm{R_{coded}} = \sum(\mathrm{H_4} + \mathrm{H_8} + \mathrm{H_{12}} + \mathrm{V_4} + \mathrm{V_8} + \mathrm{V_{12}})_{\mathrm{coded}} \quad (2)$$

Where, $\mathrm{H_4}$, $\mathrm{H_8}, \mathrm{H_{12}}, \mathrm{V_4}, \mathrm{V_8}$ and $\mathrm{V_{12}}$ are the 4th, 8th and 12th horizontal and vertical harmonics of the coded image.

Before comparing these two parameters to estimate blockiness, we have to distinguish the natural edges of the coded image from those edges (or discontinuities) due to blockiness. For this reason, the edge cancellation process is applied in order to avoid misinterpreting those natural edges which are lying on DCT block boundaries with the blocky edges. For this purpose, we first compare the strength of $\mathrm{R_{ref}}$ and $\mathrm{R_{coded}}$parameters at receiver end. Due to the fact that blockiness increases the harmonic amplitude therefore if the strength of harmonics in coded image is greater than the harmonics of reference image i.e. $\mathrm{R_{coded}} > \mathrm{R_{ref}}$, then we consider that block as 'blocky'. On the other hand, if the strength of harmonic of coded image is less than the strength of harmonic of the reference image then there is no blockiness apportioned to that block. These conditions are explained in table 1.

TABLE I. Conditions to decide the requirement of edge cancellation process in RR mode

Conditions	Comparison of each block's harmonic strength in reference and coded images	Requirement of edge cancellation process
1	$R_{coded} > R_{ref}$	Required
2	$R_{coded} < R_{ref}$	Not required
3	$R_{coded} = R_{ref}$	Not required

After the edge cancellation process, the next step is to calculate the amount of blockiness in each block. Since blockiness results from an extra luminance transition at the block boundaries therefore it increases the amplitude of harmonics in the frequency domain. The increase in harmonic amplitude in the coded image is directly proportional to the amount of blockiness distortion. Therefore by taking the difference of the coded and reference images' harmonics, $(\mathrm{R_{coded}} - \mathrm{R_{ref}})$, we estimated the blockiness artifact in each block. Finally, the blockiness of each block is accumulated in the end for a single overall blockiness metric.

V. Results

The complete algorithm for reduced reference quality meter is developed in Matlab software. Initially the work is tested on some different types of standard images with their coded versions like barbara, lena, child. After successful experiments the designed algorithm is also tested on the LIVE (Laboratory for Image and Video Engineering) image database [11] from Texas University which consists of 233 images, coded with different compression rates. All images in their database are 24 bit colored images and they have also provided the users Mean Opinion Score (MOS) in order to verify the quality of the designed algorithm. The objective scores are compared with the subjective MOS and the Pearson's correlation coefficient of 93.59% is calculated

ISSN – 1999-4974

in reduced reference mode. This result is obtained even without the training images used. Figure 3 illustrates the comparison of objective and subjective scores of the designed algorithm.

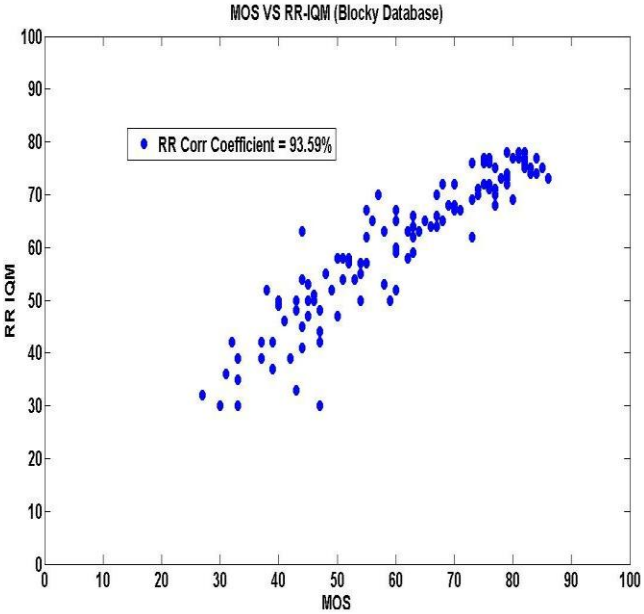


Fig. 3. Comparison of subjective and objective scores, tested on LIVE image database [9]

VI. CONCLUSION

In this paper, we proposed the reduced reference blockiness meter using frequency domain analysis. The main idea was to compare the strength of harmonics of the coded and reference images. Since blockiness results in abrupt luminance changes at DCT block boundaries, therefore by comparing the harmonics of coded and reference images, we can estimate blockiness distortion. For this reason, the reference image has gone through the edge detection, spatial masking, block processing and frequency domain analysis stages to determine the amplitudes of ac coefficients lying at DCT block boundaries, called as reduced reference parameter, R_{ref}. These harmonics of the reference image are used as reduced reference parameter and sent to the receiver end to determine the quality of the coded image. Similarly, at the receiver end, the strength of harmonics is calculated by applying the same processes and the parameter R_{coded} is calculated. In order to avoid misinterpreting textual edges lying at DCT block boundaries, edge cancellation process is also applied as discussed in table 1. The blockiness distortion of each block is calculated by comparing the reduced reference parameter with the coded image. Finally the blockiness index of the complete coded image is calculated by taking the average blockiness of all blocks. The designed meter shows very high correlation coefficient when tested with the LIVE image database [9]

REFERENCES

[1] A. Punchihewa, D. Bailey, and R. Hodgson, "Objective quality assessment of coded images: the development of new quality metrics," in International Conference on Internte and Telecommunication, pp. 1-6, 2004.

[2] M. Qadri, K. Tan, and M. Ghanbari, "Frequency domain blockiness measurement for image quality assessment," IEEE Conference on Computer Technology and Development (ICCTD), pp. 282-285, Cairo, Egypt, 2010 .

[3] M.T. Qadri, K.T. Tan and M. Ghanbari, "Frequency Domain Blockiness and Blurriness Meter for Image Quality Assessment, International Journal of Image Processing (IJIP), pp. 282-285,Volume (5) Issue (3), July 2011. (ISSN Number 1985-2304).

[4] M. Tahir Qadri, J. Woods, K.T. Tan and M. Ghanbari, "Use of Average Luminance Value for Blurriness Estimation in No Reference Mode", 1st International Young Engineers Convention, UET, Lahore , 18-20 April 2014.

[5] M.T. Qadri, J. Woods, K.T. Tan and M. Ghanbari, "Temporal Masking in No Reference Mode using Motion Vectors Analysis", ICIC Express Letters, pp. 2913-2920, Vol. 7, Issue 11, November 2013. ISSN Number (1881-803X)

[6] Y. Wang, "Survey of objective video quality measurements," EMC Corporation Hopkinton, vol. 1748, 2006.

[7] P. Vuilleumier, J. L. Armony, J. Driver, and R. J. Dolan, "Distinct spatial frequency sensitivities for processing faces and emotional expressions," Journal of Nature Neuroscience, vol. 6, pp. 624-631, 2003.

[8] R. Chan and P. Goldsmith, "A psychovisually-based image quality evaluator for JPEG images," IEEE International Conference on Systems, Man, and Cybernetics, vol 2, pp. 1541-1546, Nashville, 2000.

[9] R. Wai-Shan Chan and P. Goldsmith, "Modeling and validation of a psychovisually based image quality evaluator for DCT-based compression," Journal of Signal Processing: Image Communication, vol. 17, issue 6, pp. 485-495, July 2002.

[10] S. S. Hemami and A. R. Reibman, "No-reference image and video quality estimation: Applications and human-motivated design," Journal of Signal processing: Image communication, vol. 25, issue 7, pp. 469-481, August 2010.

[11] Z. Wang, H. R. Sheikh, and A. C. Bovik, "Objective video quality assessment," Book chapter: The handbook of video databases, design and applications, pp. 1041-1078, September 2003.

[12] H. R. Sheikh, Z. Wang, L. Cormack, and A. C. Bovik, "LIVE image quality assessment database release 2," released in 2005.

[13] M. Qadri and M. Ghanbari, "The Impact of Spatial Masking in Image Quality Meters," Global Journal of Computer Science and Technology, vol. 11, issue 20, 2011.

[14] A. Fiorentini and M. T. Zoli, "Detection of a target superimposed to a step pattern of illumination," Atti Fond. Giorgio Ronchi, vol. 21, pp. 338-356, 1966.

 ISSN – 1999-4974