Frequency Domain Blockiness and Blurriness Meter for Image Quality Assessment

Qadri, Muhammad Tahir mtqadr@essex.ac.uk
School of Computer Science and Electronic Engineering
University of Essex
Colchester,CO4 3SQ, UK

Tan, K.T. kttan@sp.edu.sg
School of Electrical and Electronic Engineering
Singapore Polytechnic
Singapore

Ghanbari, Muhammad ghan@essex.ac.uk
School of Computer Science and Electronic Engineering
University of Essex
Colchester,CO4 3SQ, UK

Abstract

Image and video compression introduces distortions (artefacts) to the coded image. The most prominent artefacts added are blockiness and blurriness. Many existing quality meters are normally distortion-specific. This paper proposes an objective quality meter for quantifying the combined blockiness and blurriness distortions in frequency domain. The model first applies edge detection and cancellation, then spatial masking to mimic the characteristics of the human visual system. Blockiness is then estimated by transforming image into frequency domain, followed by finding the ratio of harmonics to other AC components. Blurriness is determined by comparing the high frequency coefficients of the reference and coded images due to the fact that blurriness reduces the high frequency coefficients. Then, both blockiness and blurriness distortions are combined for a single quality metric. The meter is tested on blocky and blurred images from the LIVE image database, with a correlation coefficient of 95-96%.

Keywords: Blockiness and Blurriness Measurement, Full Reference, Image Quality Assessment

1. INTRODUCTION

Block-based digital image and video compression could lead to visible distortions in the coded image or video, with dominant artifacts like blockiness and blurriness. Over the years, enormous amount of efforts had been put, and many objective measurement models have been proposed. Many quality meters are distortion specific, for example, blockiness [1-3], blurriness [4-6] and ringing [7-8]. The most popular and widely used Quality Meter is the Peak Signal to Noise Ratio (PSNR) but it doesn't correlate well with the subjective assessment results. A reliable Image Quality Meter (IQM) should include all of the degradation artifacts (such as blockiness and blurriness) and weight these artifacts individually to combine into one IQM metric. In this paper, we demonstrate the use of frequency domain analysis to measure the blockiness and blurriness artifacts. Both distortions degrade the image quality; blockiness results in discontinuities at the block boundaries and blurriness reduces the sharpness of images. Since the blockiness generates periodic pattern, and blurring degrades the image quality due to loss of high spatial frequency components, it is possible to analyze these artifacts in the frequency domain instead of spatial domain. To quantify the image quality accurately, the Human Visual System (HVS) plays an important role. It is well known that the sensitivity of human eyes varies with the frequency change and therefore the presence of textual details at locations will tend to reduce the visibility

of distortion in that area. Therefore efficient masking of distortions according to the local spatial activity can lead to a better quality meter.
The rest of this paper is organized as follows: Section II gives an overview of Harmonics Analysis; Section III explains the design of the Image Quality meter; and Section IV shows the obtained results and section V lists the used references.

2. An Overview of Harmonic Amplitude Analysis

Blockiness and blurriness are the two main distortions in the image during coding process. Blockiness is due to luminance discontinuities across DCT block boundaries. As the DCT block size is fixed (or varies in the ratio of 2), the luminance discontinuity is periodic. If these luminance discontinuities are extracted and transformed into frequency domain, harmonics at certain spatial frequencies are created due to periodicity of the luminance discontinuities. The strength of these harmonics is proportional to the degree of blockiness in the coded picture [9]. Figure 1 shows the basic concept of Harmonics Amplitude Analysis (HAA) in frequency domain.

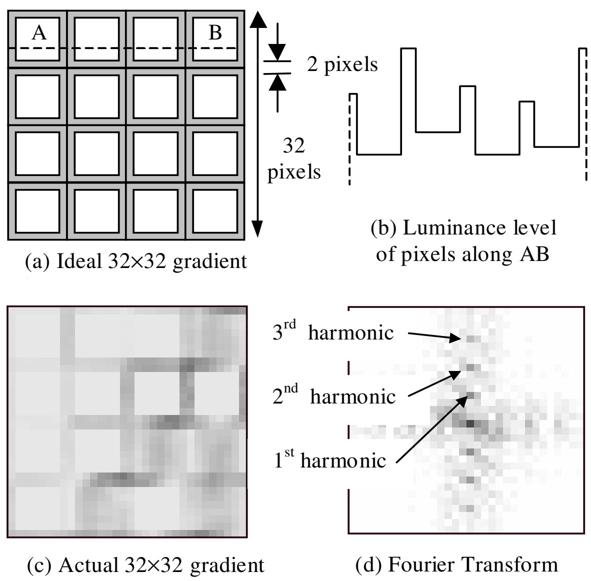

FIGURE 1: Basic concept of Harmonic Amplitude Analysis

Figure 1(a) is an ideal blocky gradient image of 32×32 while Figure 1(b) shows the luminance level transitions across 1 row of pixels. Figure 1(c) shows a 32×32 block extracted from the gradient image of a blocky picture, and Figure 1(d) is its Fourier transform, with the three vertical harmonics highlighted.

For the calculation of blockiness or blurriness index, the image is divided into blocks for block processing. The reason for block processing is that if we apply the FFT on whole image without block processing, then the chances of error is very high because the distortion might not be consistent and equal in every part of the image so the distortion is computed for each block locally and will be accumulated in the end as a single quality metric. The size 32x32 is chosen because the block size should be multiple of 8 (as DCT block size is 8x8) and the harmonics must have some distance among them to be recognized as harmonics that is why 32x32 window size is selected.

After dividing the image into blocks of 32x32 pixels, each block is transformed into frequency domain. As the frequency domain has two parts; the amplitude and phase, only the amplitude part is used in this work because blockiness or blurriness affects the amplitude part only.

For every block of 32x32, there will be 1 DC component and 32 AC components (2 repetitive groups of 16). There will be three harmonics for 32x32 window, i.e. H4, H8 and H12. For determining the harmonic frequency, recall the equation,

$$f_k = k * \left(\frac{w}{8}\right), \quad \text{for } k = 1,2,\ldots, \left(\frac{w}{8} - 1\right) \qquad (1)$$

where, f_k is the frequency of harmonics in cycles per window (cpw) and as it also depends on the width of the FFT window w. The above equation represents the harmonics in frequency domain. The next section explains the design of full reference quality meter mainly focusing the combination of two distortions.

3. DESIGN OF THE IMAGE QUALITY METER

The main emphasis of this paper is to develop a distortion meter with combined blockiness and blurriness distortions. Only blockiness meter is not good in estimating quality of lightly compressed image (very little blockiness) therefore adding a blur meter will help to compensate for that weakness. In the following parts the combined blockiness and blurriness quality meter which is designed for full reference (FR) mode is explained. It consists of 3 main parts; 1) blockiness estimation; 2) blurriness estimation and 3) combining the two distortions.

3.1 Blockiness Estimation

The blockiness estimation stage consists of 4 stages; Edge Detection; Edge Cancellation; Spatial Masking; and Blockiness Estimation in the frequency domain. Figure 2 shows a block diagram of the meter (blockiness part).

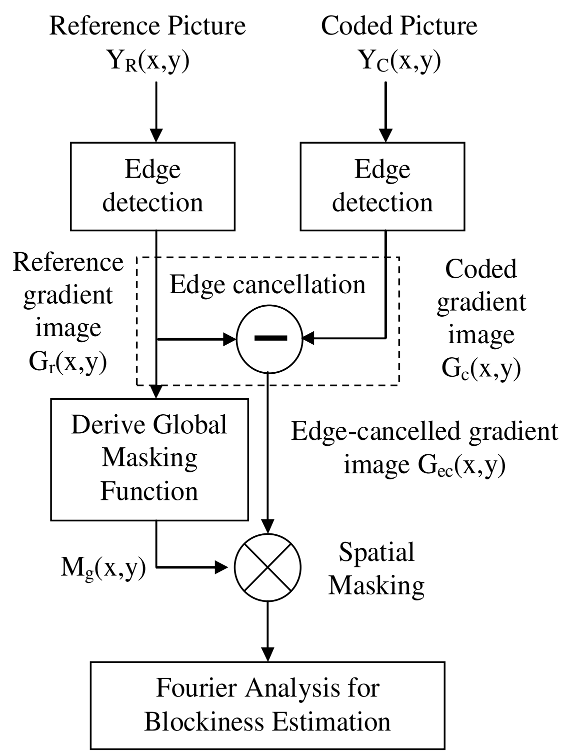

FIGURE 2: Block Diagram of the blockiness detector

3.1.1 Edge Detection

Edge detection is used to determine the sharp luminance edges from the reference image. These sharp luminance edges are either due to the blockiness artifact introduced in coding process or due to the textual details present in reference image. This spatial activity of both, reference and coded images, are determined by using sobel edge detectors. The edge detection is performed horizontally and then vertically on both images.

3.1.2 Edge Cancellation

Some heavy textual details in the reference image might also be misinterpreted as blockiness, so the edge cancellation process is performed between edge detected versions of coded and reference images to reduce the chance of misinterpreting the contextual details as blockiness. It leaves only the edges due to blockiness. Also note that, the coding process also removes the high frequency coefficients so the simple subtraction of reference image from coded image will not perform effective edge cancellation. So, the pixel comparison is done between the coded and reference image to check if the pixel value of coded image is greater than the reference pixel value only then subtract the reference picture from the coded image as explained in equation below. The equation below is used to apply the edge cancellation process.

$$G_{ec}(x,y) \qquad \begin{cases} Gc(x,y) - Gr(x,y) & \text{if } Gc(x,y) > Gr(x,y) \\ 0 & \text{Else} \end{cases}$$

where, $G_{ec}(x,y)$ is the edge cancelled gradient image, $Gc(x,y)$ is the edge detected coded image and $Gr(x,y)$ is the edge detected reference image. Now, the edge cancelled gradient image contains spatial activity only due to blocking artifact.

3.1.3 Spatial Masking

The next part is to mask the edge cancelled gradient image according to the spatial activity present in the reference image. The spatial masking is performed because perception of blockiness in detailed areas can be more masked than in low detailed areas of the picture. To derive the global masking function $M_g(x,y)$, the edge detected version of the reference image is used. For each pixel in the gradient reference image $G_R(x,y)$, a local masking function $m_g(x,y,\delta)$ is derived. Then these local masking functions are used to obtain the global masking function $M_g(x,y)$ which contains the spatial activity of the reference image. In this work, the spatial masking from Fiorentini and Zoli [10] is adopted. The masked reference image is convolved with the edge cancelled gradient image. After the edge cancellation and spatial masking, the edge cancelled spatial masked gradient image is ready for Fourier transformation for quantifying the blockiness.

3.1.4 Frequency Domain Analysis

Based on the concept of harmonics in frequency domain, the Harmonic Amplitude Analysis (HAA) method is proposed for blockiness estimation, in which the comparison of the strength of harmonics with other AC components is performed. Since blockiness is the abrupt luminance changes so it creates the harmonics in frequency domain and the strength of these harmonics are directly proportional to the amount of blockiness in the coded image.

The local blockiness index for each block is calculated by comparing the strength of harmonics with the rest of AC components. The higher the blockiness in an image, the higher will be the harmonics to AC components ratio and higher will be the blockiness. The equation for the Amplitude Harmonic Analysis ratio is given below:

$$R = \frac{\sum (H_4 + H_8 + H_{12})}{\sum_{n=1}^{15} H_n}$$

The amplitude harmonic analysis ratio R is calculated both vertically and horizontally and then accumulated in the end for a single blockiness metric.

3.2 Blurriness Estimation

Blurriness occurs over the whole image by reducing the sharpness of image due to the loss of high frequency coefficients and it is easier to determine blurriness in frequency domain by analyzing the high frequency coefficients. The amount of blurriness is estimated by comparing the high frequency coefficients of reference and coded images.

The blurriness distortion also needs to be masked according to the local spatial activity from the reference image. The same spatial masking concept (which was used for blockiness meter) is used to determine the spatial activity of the reference image. After determining the spatial activity, the coded image is multiplied with the masked image so that the distortion is weighted according to the details present in the coded image. The high frequency coefficients of the masked coded and masked reference images are compared to determine the amount of blurriness. The block diagram for the blurriness meter is explained in figure below.

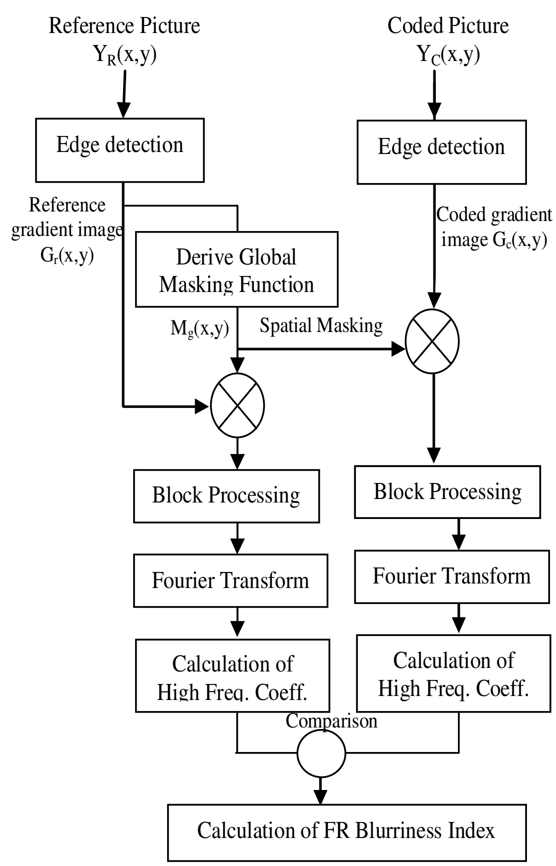

FIGURE 3: Block Diagram of blurriness detector

The blurriness estimation stage consists of 3 stages; Edge Detection; Spatial Masking; and analysis of high frequency coefficients.

First, the edge detection process is performed to determine the gradient of the reference and coded image. Then the edge detected version of the reference image is used to determine the spatial activity of the image for masking the blurriness distortion according to the local spatial activity of the reference picture in the form of masked image. Then the masked image is convolved with both, the edge detected reference image and edge detected coded image to weight the blurriness according to the spatial activity from the reference image. These steps are same as performed for the blockiness part.

Finally, the blurriness metric is calculated by comparing the high frequency coefficients of the masked reference and masked coded images in frequency domain. After calculation of the blockiness and blurriness indexes, the two distortions are combined together as explained in section below.

3.3 Combining Blockiness and Blurriness

The last stage of the blockiness and blurriness meter is to combine the two artifacts. As mentioned earlier, summation of blockiness and blurriness artifacts is not linear because both distortions have different visual impacts on the viewers. So first, they must be weighted accordingly and then added for a single quality metric.

To explain their combination phenomenon, 'bikes' image is compressed at different compression rates and the number of dominant blurred and blocky blocks (of 32×32 pixels) are calculated by comparing the reference and coded images.

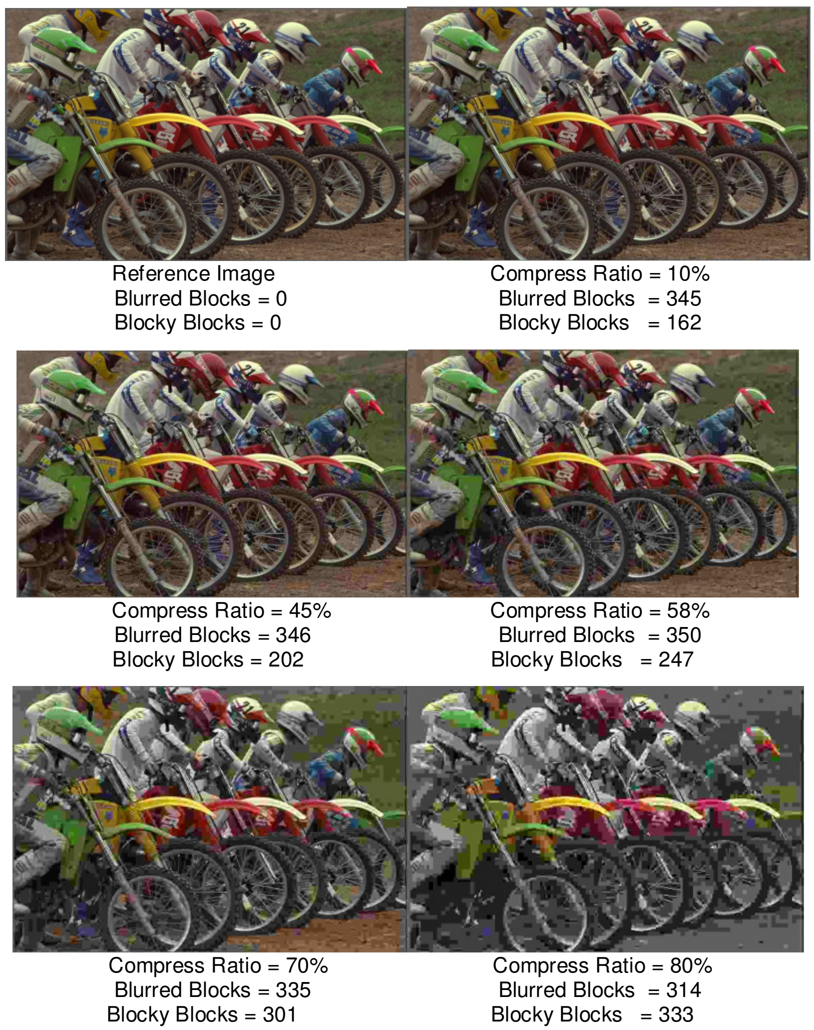

FIGURE 4: Bikes image compressed at different ratios

To understand the combination strategy of blockiness and blurriness artifacts we have to study their behavior and appearances in the images. As the compression ratio is increased, images tend to lose their higher frequency contents, due to their smaller energy they carry and appear blurry. When the compression becomes very severe, then the picture becomes blocky as can be seen in figure 4. This means, blockiness is an ultimate consequence of blurriness. Once the blockiness starts appearing, it means the image has already gone through the blurriness artifact and the blurriness is saturated. By further compressing the image, blockiness artifacts starts appearing and it becomes dominant on blurriness artifact and user starts observing blockiness in image. Finally for the combination of two distortions, more weightage should be given to blurriness at low compressions and at higher compression rates to blockiness. The following graphs for blurriness and blockiness weighting functions are estimated based on tests on various images of the data base.

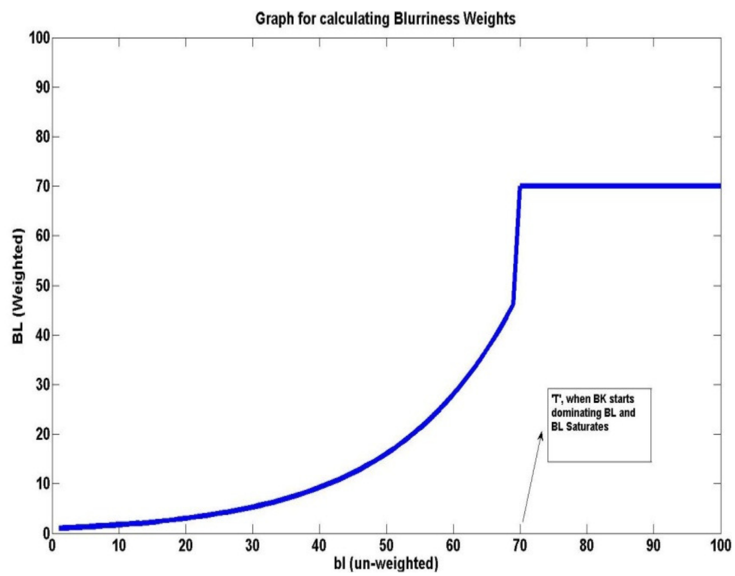

FIGURE 5: Blurriness weighting function graph

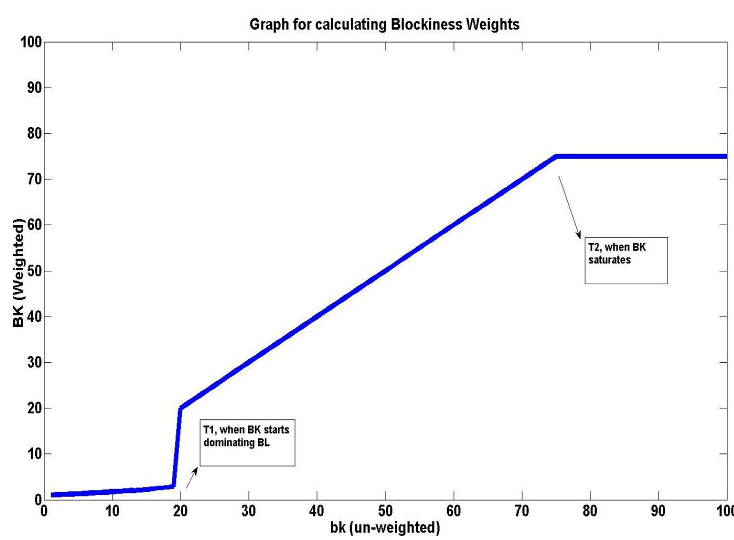

FIGURE 6: Blockiness weighting function graph

The above graphs highlight the combination of blockiness and blurriness artifacts. At low compression rates blurriness artifact appears so more weightage is given to blurriness at low compressions while the weightage of blockiness is more at high compression rates. The above distortion meter is tested on both blocky and blurred database from LIVE image database [11].

4. CONCLUSION

The main emphasis of the paper is to combine blockiness and blurriness distortions. As a fact that at low compressions blurriness comes first because of the loss of high frequency coefficients, after saturation of blurriness, blockiness artifact starts to appear as explained in figure 4. To combine these two artifacts, different weightage is given to both distortions. The complete algorithm was built in MATLAB software. The IQM is tested on blocky and blurred images from LIVE image database [11], and the results were compared with the users' Mean Opinion Score (MOS). The graph comparing MOS and IQM is shown below.

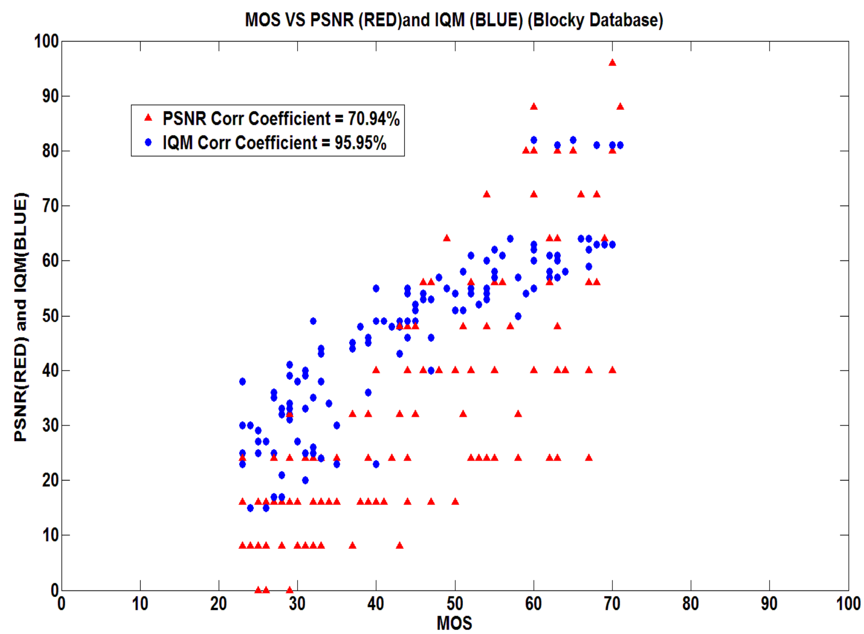

FIGURE 7: Comparison of the MOS and the objective quality for blocky image database from LIVE database

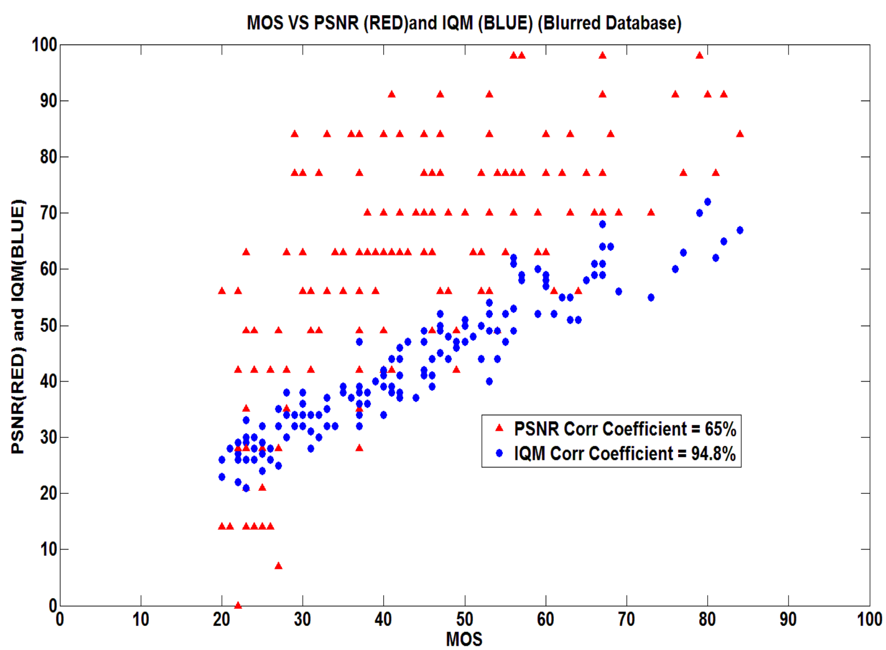

FIGURE 8: Comparison of MOS and the objective quality for blurred image database from LIVE database

Pearson's Correlation Coefficient (FR-Combined BK,BL) = 95.95 % *(on blocky image database)*
Pearson's Correlation Coefficient (FR-Combined BK,BL) = 94.8 % *(on blurred image database)*

5. REFERENCES

[1]. Z. Wang and E. P. Simoncelli, "Reduced-Reference Image Quality Assessment Using A Wavelet-Domain Natural Image Statistic Model", Proceedings of SPIE Human Vision and Electronic Imaging X, vol. 5666, San Jose, CA, 2005, pp. 149–159.

[2]. Z. Wang, A. C. Bovik, and B. L. Evans, "Blind measurement of blocking artefacts in images," in IEEE Int. Conf. Image Processing, September 2000, vol. 3, p. 981-984, IEEE.

[3]. L. Meesters and J. B. Martens, "A single-ended blockiness measure for JPEG-coded images", Signal Process., Vol. 82, pp. 369-387, 2002.Z.

[4]. M. Parvez Sazzad, Y. Kawayoke, and Y. Horita, "No-reference image quality assessment for jpeg2000 based on spatial features," Signal Processing: Image Communication, vol. 23, no. 4, pp. 257–268, April 2008.

[5]. X. Zhu and P. Milanfar, "A no-reference sharpness metric sensitive to blur and noise", QoMEX, 2009. July 29–31, 2009, San Diego, California, U.S.A.

[6]. M. G. Choi, J. H. Jung, and J. W. Jeon, "No-Reference Image Quality Assessment using Blur and Noise," in International Journal of Computer Science and Engineering 3:2 2009, pp. 76–80.

[7]. R. Barland and A. Saadane, "A new reference free approach for the quality assessment of mpeg coded videos," in 7th Int. Conf. Advanced Concepts for Intelligent Vision Systems, Sep. 2005, vol. 3708, pp. 364–371.

[8]. X. Feng and J. P. Allebach, "Measurement of ringing artifacts in jpeg images," in Proc. SPIE, Jan. 2006, vol. 6076, pp. 74–83.

[9]. K. T. Tan, M. Ghanbari, "Frequency domain measurement of blockiness in MPEG-2 coded video," Proceedings of ICIP 2000, Vol. 3, pp.977 – 980.

[10]. Fiorentini, A. and Zoli, M. T., "Detection of a Target Superimposed to a Step Pattern of Illumination. II. Effects of a Just-Perceptible Illumination Step", Atti. Fond. G. Ronchi, Vol. 22, pp. 207-217,1967.

[11]. Live website for subjective scores MOS. http://live.ece.utexas.edu/research/quality/

[12]. Z. Wang and A.C. Bovik, "A universal image quality index", IEEE Signal Processing Letters, 9(3):81–84, March 2002.

[13]. Qadri, M.T. Tan, K.T. and Ghanbari, M., "Frequency domain blockiness measurement for image quality assessment ", IEEE International Conference on Computer Technology and Development (ICCTD), pp. 282 – 285, Cairo,2-4 Nov. 2010.