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A Novel Hybrid Approach to Quality Assessment Using No Reference Blur and Blockiness Measure in JPEG Images

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Abstract:
This paper aims to combine the effects of blurring and blocking on a JPEG image to devise a quality metric that correlates well will human vision. Blurring is caused due to the degradation of the high frequency components in an image. Blocking is another irregularity that is present in images that use block based coding. It is also called as quilting or checker boarding. Both these artifacts greatly reduce quality of the images. Blurring is estimated using multi-scale quadrature filters and blocking is measured using perceptual blockiness method. Both the blurring and blockiness estimation methods are combined using a weighted approach based on thresholding.

Key words: *blur, blocking, quality assessment*

1. Introduction

Image and video quality assessment has come to be of great importance. The objective of quality metric is to provide an automatic and efficient system to successfully evaluate image quality. Many image quality metrics, like mean square error (MSE) and peak signal to noise ratio (PSNR) do not correlate well with human perception. This makes it necessary for comparison with a reference image. The reference image must be free from irregularities and various distortions. Many a times, a reference image is not necessarily available. This type of assessment is known as the full-reference method. This paved the way for no reference method of quality assessment. This paper combines blurring and blocking artifact measures to come up with a quality metric for compressed images. This method correlates well with human perception.

Blurring is caused due to attenuation of high frequency components. It occurs during filtering as well as during compression. Blurring makes an image unfocused. A fuzzy image is of lower quality and it becomes difficult to distinguish between features in an image. Block based compression techniques like Discrete Cosine Transform (DCT) introduce blockiness in images. JPEG uses block based DCT compression and it suffers from blockiness. The degree of quantization determines the degree of blockiness. The blurring and blocking in images is shown in Figure.1 shows the original undistorted image, Figure.2 shows the image distorted with blocking and Figure.3 shows the image distorted with blur. The quality metric proposed in this paper combines blurriness and blockiness metric to estimate the overall image quality. The results are evaluated using single stimulus methodology (J. Redi et al., 2010) on images from the LIVE database (H.R. Sheikh et al.).

Figure 1: Original Image
Figure 2: Blockiness in the Image
Figure 3: Blurriness in the Image

2. Methodology

2.1. No Reference Blur Estimation Method

The blur estimation method (S. Soleimani et al., 2013) is a multi scale quadrature filter based method of blur estimation. The response is obtained in a scale independent manner, and it is attained at the center of the feature. This differentiates it from other scale dependent methods (C. Ducottet et al., 2003) where the responses shift with scale. Use of quadrature filters instead of only first order derivatives of Gaussian for multi-scale edge detection ensures scale independent responses.

The blur estimation methodology employs modeling the image into transition and line type. The transition edge corresponds to the boundaries of the image. The line model is taken as the convolution product of a one dimensional Dirac function with a Gaussian function. The singularities are modeled as transitions ($T_\sigma(x,y)$) and lines ($L_\sigma(x,y)$) as is described in the Eq.1-4.

$$T_\sigma(x,y) = AH(x) * G_\sigma(x,y) = \frac{A}{2}\left(1 + \text{erf}\left(\frac{x}{\sigma\sqrt{2}}\right)\right) \quad (1)$$

$$L_\sigma(x,y) = 2\pi\sigma^2 A\delta(x) * G(x,y) = 2\pi\sigma^2 A\, G(x,0) \quad (2)$$

$$G_\sigma(x,y) = \frac{1}{2\pi\sigma^2}\exp\left(-\left(x^2 + y^2\right)\right) \quad (3)$$

$$\text{erf}(x) = \frac{2}{\sqrt{\pi}}\int_0^x \exp\left(-t^2\right) \quad (4)$$

The main property of using the energy of quadrature filters for edge detection is that one of its responses to both transition-type and line-type features always occurs at the centroid of every feature. The energy of the image response to the pair of first and second derivatives of the Gaussian is given by Eq. 5.

$$E(x,y,s,\theta) = \left(f'(x,y,s,\theta)\right)^2 + \left(f''(x,y,s,\theta)\right)^2 \quad (5)$$

The extrema function of the transition model is given by Eq. 6

$$ME T_\sigma(s) = \frac{A^2 s^2}{2\pi(s^2+\sigma^2)} \quad (6)$$

The extrema function of the line model is given by Eq. 7

$$ME L_\sigma(s) = \frac{A^2 s^4 \sigma^2}{((s^2+\sigma^2))^2} \quad (7)$$

2.2. Algorithm

1. f_x , f_y, f_{xx} and f_{yy} are calculated in several scales.
2. The energy extrema is found in every scale.
3. Extrema functions of the models are fitted to the extracted extrema functions for classification to transition or line and also to estimate the blur level.
4. The average of blurriness of all detected edges is calculated.

The flow chart for the blur estimation method is as shown below in Figure 4.

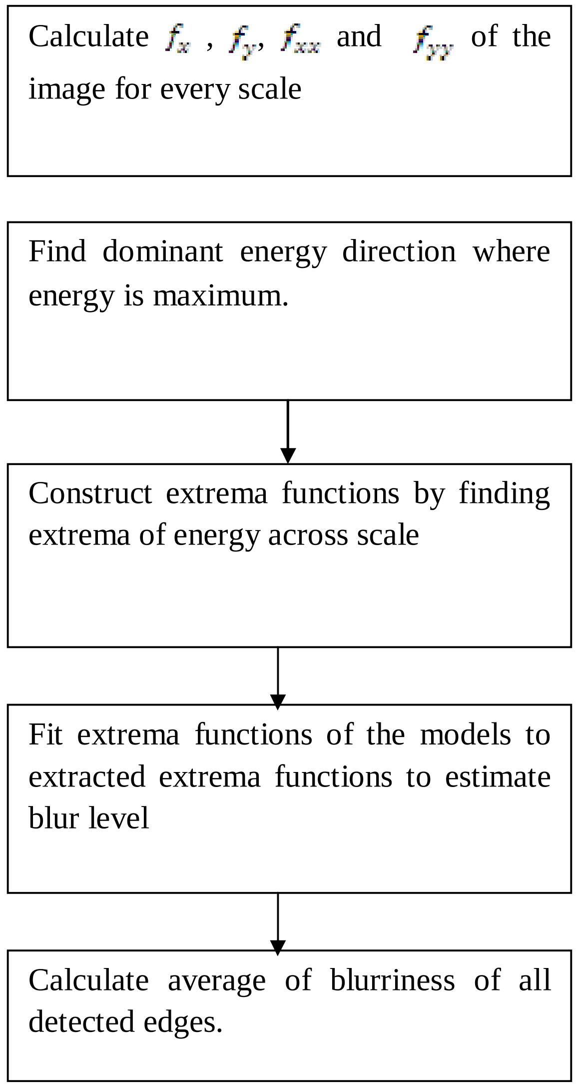

Figure 4: Flowchart of Blur Estimation Method

2.3. No Reference Blockiness Estimation Method

The blurriness measure is calculated using various features of the image like edge amplitude, edge length, background luminance and background activity (R.V. Babu et al., 2004). The algorithm is as shown below and flowchart is shown in Figure. 5.

2.4. Algorithm

1. Obtain the horizontal map (Eh) using thresholding with threshold value $t1$, set at 3.5

$$\widetilde{Eh} = I * P_h \qquad (8)$$

$$E_h(i,j) = \begin{cases} \widetilde{Eh}(i,j) : if\ \widetilde{Eh}(i,j) < t1 \\ 0 \quad : otherwise \end{cases} \qquad (9)$$

where,

$$P_h = 1/3\begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix} \qquad (10)$$

2. Obtain the horizontal activity mask (Mh) using Eq. 11,12

$$A_h = I * F_{ah} \qquad (11)$$

where,

$$F_{ah} = \begin{bmatrix} 1 & -1 & 1 & -1 & 1 & -1 & -1 & 1 & -1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ -1 & 1 & -1 & 1 & -1 & 1 & 1 & -1 & 1 \end{bmatrix} \quad (12)$$

3. Perform masking the edges using a threshold value t2, set at 0.15.

$$M_h(i,j) = \begin{cases} 1 : if\ A_h(i,j) < t2 \\ 0 : otherwise \end{cases} \quad (13)$$

4. Obtain the background Luminance weight (W_l) as in Eq.14

$$W_l(i,j) = \begin{cases} \sqrt{\frac{I_l(i,j)}{128}} : if\ 0 \leq I_l(i,j) < 128 \\ 1 : otherwise \end{cases} \quad (14)$$

where,

$$I_l = I * f_{tp} \quad (15)$$

$$f_{tp} = \left(\frac{1}{4}\right) \begin{bmatrix} 1 & 0 & 1 \\ 0 & 0 & 0 \\ 1 & 0 & 1 \end{bmatrix} \quad (16)$$

5. Obtain final weighted edge image in horizontal direction as in Eq.17

$$E_H(i,j) = E_h(i,j) \times M_H(i,j) \times W_l(i,j) \quad (17)$$

6. Obtain vertical profile as:

$$P_v(i) = \sum_{j=1}^{N} E_H(i,j) \quad (18)$$

7. Horizontal blockiness measure is calculated as:

$$B_H = \frac{1}{M} \sum_i |P_{v1}(i) - P_{vm}(i)| \quad (19)$$

$$P_{v1} = P_v(8n) \quad (20)$$

and

$$P_{vm}(n) = \overline{P_{vc}}(8n) \quad (21)$$

$$P_{vc} = median(P_v) \quad (22)$$

8. In the same way as above obtain the vertical blockiness measure using vertical map
9. Calculate total blockiness measure as in Eq. 23

$$\tilde{B} = \sqrt{B_H + B_V} \quad (23)$$

10. The final blockiness measure is given by Eq. 24

$$B = 10(1 - \tilde{B}) \quad (24)$$

The flow chart for the block estimation method is as shown below in Figure 5.

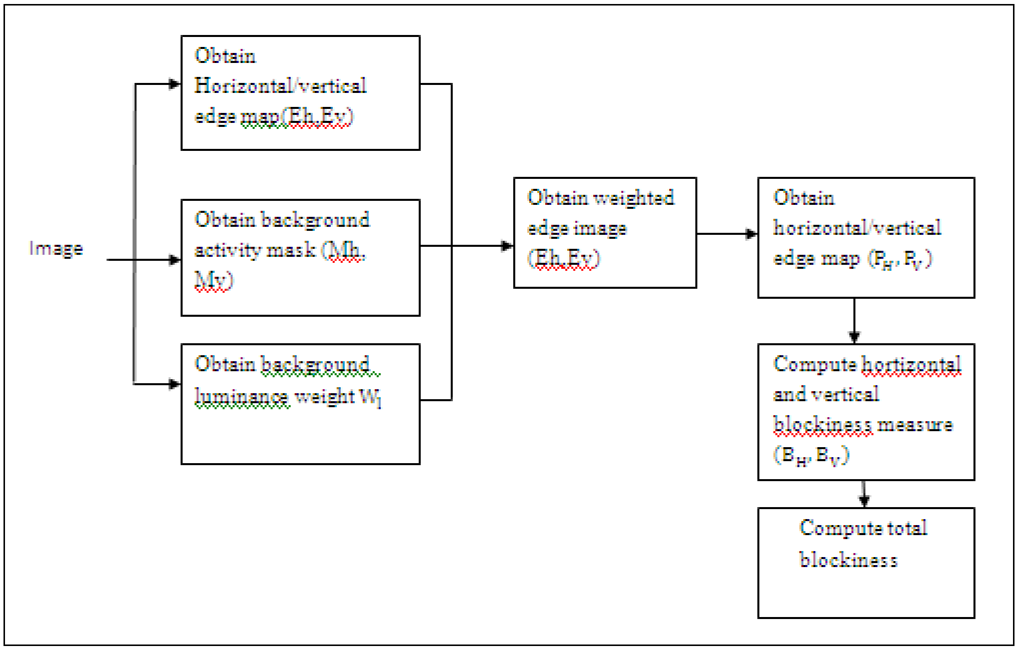

Figure 5: Flowchart of Method to Estimate Blockiness

2.5. Hybrid Approach or Image Quality Assessment

The quality metric proposed in this paper combined both the above mentioned blur and block estimation techniques in a weighted approach. The flow chart for this method is shown in Figure.6.

2.6. Algorithm

- The blur metric is computed using the no reference multi-scale quadrature filter blur estimation method.
- The blocking metric is computed using the no reference blockiness metric described earlier.
- Using appropriate weights, the blurriness and blockiness metric is combined to reduce the error.
- The weighted blur and blockiness metric is combined to obtain the quality metric.

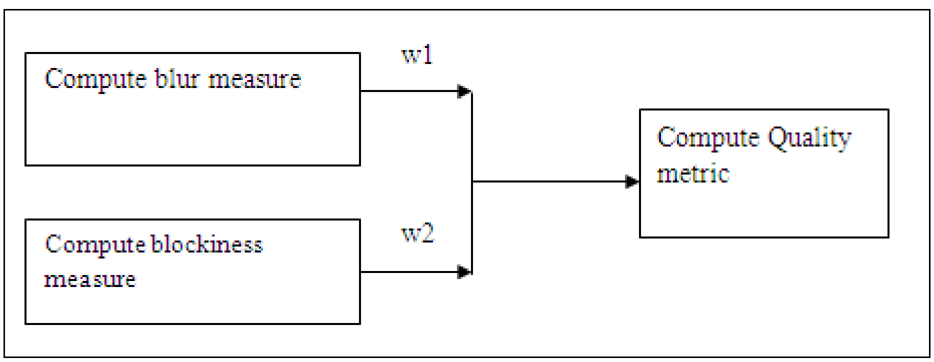

Figure 6: Flowchart of Method to Estimate Quality Metric

3. Performance metrics

Spearman correlation coefficient is the correlation between ranked variables. In this paper, the quality metric obtained is checked for correlation with the subjective ratings provided by 5 viewers. The viewers were asked to evaluate 32 images in a neutral environment. The viewers were each provided with 10 seconds to provide their ratings. A completely neutral gray image was shown in between images to the viewers to neutralize the eye and to remove any effects of image burn-in or after image. Such effects could adversely affect the evaluation. The ratings were provided based on the level of distortion that the viewers could perceive (Z.Wang et al., 2002). Finally average of all the ratings from the viewers were selected as the subjective rating for each image. The ratings were given as follows

Rating	Description
5	Terrible image quality, heavily distorted
4	Bad image quality, medium distortion
3	Fair image quality with lesser distortion
2	Good image quality, low distortion
1	Very good image quality, very little distortion

Table 1: Viewer Ratings Based On Image Quality

4. Results

8 sets of images each of monarch and statue are considered for evaluation. Also, the results are evaluated after introducing a blur of STD=25 on the images. Therefore a total of 32 images are considered for evaluation.

Statue JPEG compressed images from LIVE					**Statue image with Gaussian blur , STD=25**	
Bit Rates	**Estimated Blur Value**	**Blockiness Value**	**Quality Metric**	**Subjective Rating**	**Quality Metric**	**Subjective Rating**
0	36.761	8.84	80.961	5	39.007	5
0	36.761	9.942	86.471	5	39.007	5
0.165	30.396	9.942	80.106	1	73.942	5
0.165	30.396	9.596	78.376	1	73.942	5
0.296	35.953	9.197	81.938	3	73.505	4
1.103	35.978	8.836	80.158	5	39.957	1
2.195	36.237	8.863	80.552	5	74.330	5
2.777	36.33	10	86.333	5	38.871	1
Spearman Correlation coefficient			0.6972		0.6432	

Table 2: Spearman Correlation Coefficient for Statue Image

Monarch JPEG compressed images from LIVE					**Monarch image with Gaussian blur , STD=25**	
Bit Rates	**Estimated Blur Value**	**Blockiness Value**	**Quality Metric**	**Subjective Rating**	**Quality Metric**	**Subjective Rating**
0.32107	59.395	10.000	109.395	5	89.597	5
0	60.626	6.227	73.080	1	54.143	1
0.77547	60.502	9.649	108.751	4	88.442	4
2.6482	60.672	6.704	74.082	3	54.139	3
0.1814	53.038	10.000	103.038	5	86.184	5
0.60179	59.588	9.784	108.509	4	88.842	4
0.1814	53.038	10.000	103.038	5	86.184	5
0	60.626	6.227	73.080	1	54.143	1
Spearman Correlation coefficient			0.6916		0.52923	

Table 3: Spearman Correlation Coefficient for Monarch Image

5. Conclusion

In this paper a new hybrid no-reference method of estimation of quality metric in JPEG images was proposed. This technique employs a combination of the degree of blurriness and degree of blockiness in an image. The results obtained were evaluated against the results of subjective evaluation by viewers. The Spearman correlation coefficient of the images that were evaluated were found and a good correlation is obtained. A further area for improvement would be to consider the ringing effects produced in JPEG images.

6. References

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