

Blur and Ringing Artifact Measurement in Image Compression using Wavelet Transform

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Abstract—Quality evaluation of an image is an important task in image processing applications. In case of image compression, quality of decompressed image is also the criterion for evaluation of given coding scheme. In the process of compression –decompression various artifacts such as blocking artifacts, blur artifact, ringing or edge artifact are observed. However quantification of these artifacts is a difficult task. We propose here novel method to quantify blur and ringing artifact in an image.

Keywords—Blur, Compression, Objective Quality assessment, Ringing artifact.

I. INTRODUCTION

BLUR in an image is due to the attenuation of the high spatial frequencies, which commonly occurs during filtering or visual data compression. Measurement technique of the perceptual blur in an image or a video sequence has not yet been investigated much, related research topics include blur identification, blur estimation [1], image de-blurring [2] Ringing in an image are caused by the quantization or truncation of the high frequency transform coefficients resulting from DCT- or wavelet-based coding. In the spatial domain this causes ripples or oscillations around sharp edges or contours in the image. This is also known as the Gibbs phenomenon. A method for the detection of ringing effect parameters for restoration is presented in [3].

Most of the papers cited above do not attempt to measure the perceptual impact of these artifacts. However, it is of great importance to be able to objectively quantify the perceived blur and ringing in an image. The goal is to establish metrics, which correlate with the human visual experience by mapping the objective measurements onto subjective test results.

To assess overall quality of the image various objective parameters are given by [5][6][7]. These parameters do not consider any artifact in isolation but gives overall degradation result. When we want to investigate effect of processing technique in terms of artifacts, these parameters are not suitable. Pina Marziliano [4] has given procedure to measure ringing and blur measurement.

Here for every edge in reference image and de-compressed image, edge width is measured. Difference in width is blur indication. For ringing metric edge width in reference image and difference image (pixel wise difference between reference image and processed image) is considered. Thus method to measure blur and ringing is very complicated especially for natural images. Another approach is taken by M. Balasubramanian et al. to find ringing for restored image [8]. Here using canny detector edges of reference image are found. By dilating these edges binary mask is created. Edge profile of Processed image undergoes pixel wise ‘AND’ operation with this mask. Difference between masked edges in processed image and reference edges is used as ringing metric. [9] uses area near the edge region to find blur. These methods are complicated and computationally complex.

We present simple method to measure blur and ringing artifact using Wavelet transform.

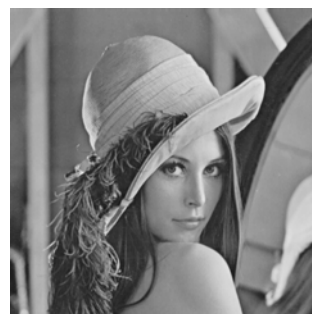


Fig. 1 Original Image

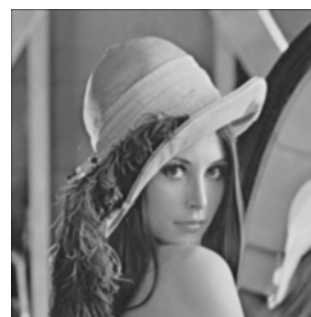


Fig. 2 Image blurred due to low pass filtering
Eye and hair portion shows noticeable blur

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Fig. 3 Blocking observed in JPEG



Fig. 4 Ringing artifact

II. NEW BLUR AND RINGING ARTIFACT MEASURE

A. Wavelet Decomposition of the Image

Using analysis and synthesis bank image can be decomposed to get frequency spectrum at different resolution. Typical two level wavelet decomposition of synthetic image Fig. 5 (a), is shown in Fig. 5 (b)

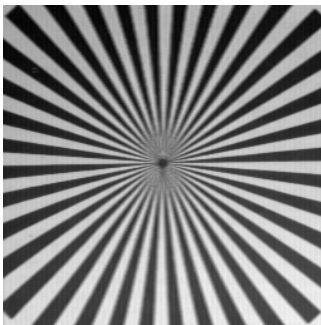


Fig. 5 (a) Original Image

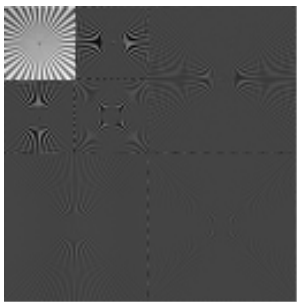


Fig. 5 (b) Wavelet decomposition

B. Correlation between Coefficients

If we find Wavelet decomposition of the image, we know that LH, HL, and HH bands show edges in horizontal vertical and diagonal directions respectively. When the image is blurred it affects edges or variations in an image. Blurring gives thick edges. Ringing problem also affects edges but ringing generates oscillation around the edges. This effect can be easily observed in wavelet domain.

LH orientation gives edges in vertical direction. When image get blurred the edges become thicker or they are not sharp. Hence we expect that correlation between adjacent pixels in the same row (column) for LH (HL) orientation will increase.

In case of ringing effect oscillations are observed around edges. This may reduce the correlation between adjacent pixels in the same row (column) for LH (HL) orientation. To verify our guess we examined row and column profiles for sample images. As an example Fig. 6 is horizontal profile of LH2 band of Lena image. When image is compressed using SPIHT compression scheme edge blur as well as ringing artifact occurs. However ringing artifact is more predominant than blur. If we plot profile of same row in LH2 before compression and after compression we can find that profile shows more variations or more oscillations.

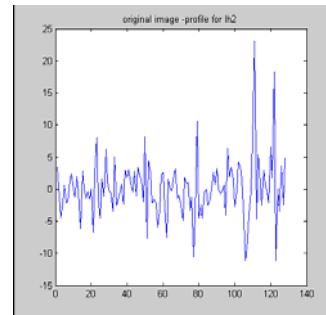


Fig. 6 (a) Horizontal Profile in LH2 band for image Lena

If image is filtered using low pass filter due to edge blurring horizontal profile shows less variation

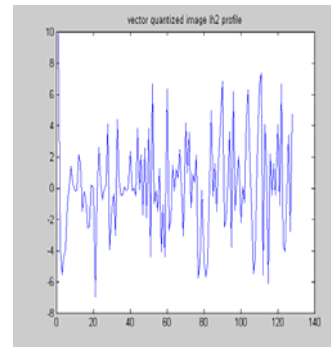


Fig. 6 (b) Horizontal Profile in LH2 band for same row (SPIHT) compressed image

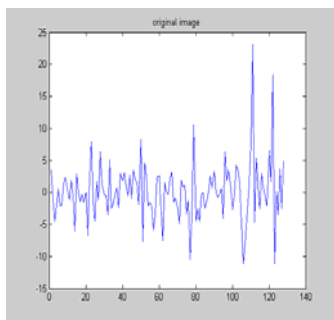


Fig. 7 (a) Horizontal Profile in LH2 band for image Lena

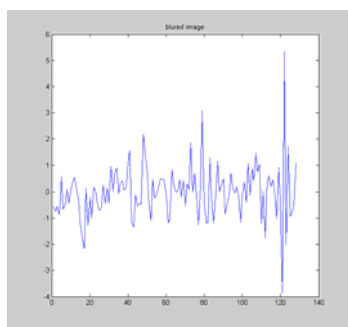


Fig. 7 (b) Horizontal Profile in LH2 band for same row Low pass filtered Image

For blurred image it is found that correlation in all bands between adjacent pixels (same row previous column) is more than original. More the blurring more rise in correlation value while if it is edge-ringing correlation is reduced. Based on this observation we propose following algorithm for edge artifact and blur measurement.

III. BLUR AND EDGE ARTIFACT CALCULATION

A. Flow Chart

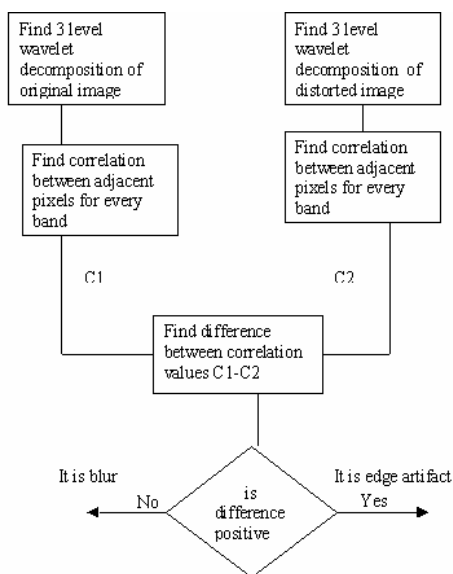


Fig. 7 Flow chart for blur and ringing artifact measurement

B. Blur and Edge Artifact Measure

Referenc image and decompressed image are transformed into wavelet domain, three level decomposition is used. Correlation between reference pixel and pixel in same row and previous column is calculated for every band of reference image (c_1) and decompressed image (c_2), using Pearson's correlation. Steps for calculation are

$$\bar{I} = \frac{1}{N * M} \sum_{i=0}^{n-x} \sum_{j=0}^{m-y} I(i, j) \quad (1)$$

Where $I(i,j)$ - wavelet coefficient at i^{th} row and j^{th} column
 N = number of rows
 M = number of columns in the given Image

$$\bar{S} = \frac{1}{N * M} \sum_{i=0}^{n-x} \sum_{j=0}^{m-y} I(i + x, j + y) \quad (2)$$

$x = 0, y = 1$

$$SQI = \sqrt{\sum_{i=0}^{n-x} \sum_{j=0}^{m-y} (I(i, j) - \bar{I})^2} \quad (3)$$

$$SQS = \sqrt{\sum_{i=0}^{n-x} \sum_{j=0}^{m-y} (I(i + x, j + y) - \bar{S})^2} \quad (4)$$

$$R_{xx} = \frac{\sum_{i=0}^{n-x} \sum_{j=0}^{m-y} (I(i, j) - \bar{I}) * (I(i + x, j + y) - \bar{S})}{SQI * SQS} \quad (5)$$

If difference, $c_1 - c_2$ is positive it is treated as edge artifact otherwise it is blur. Difference $c_1 - c_2$ is found for all bands positive values are added together which gives total edge artifact while addition of all negative values gives overall blur.

On account of sensitivity of the eye being different for different spatial frequencies, we introduce weight as 2 for resolution level 3, 1.414 for resolution level 2 and 1 for resolution level 1.

Thus edge artifact value= $2 * (\text{ringing artifact at resolution level 3}) + 1.414 * (\text{ringing artifact at resolution level 2}) + (\text{edge artifact at resolution 1})$

Total blur value= $2 * (\text{blur artifact at resolution level 3}) + 1.414 * (\text{blur artifact at resolution level 2}) + (\text{blur artifact at resolution 1})$

To validate the result we compared it with subjective test taken. Subjective tests are mainly done used for overall quality. However we have carried out the subjective test for

Blur and ringing. To carry out subjective assessment MOS test was conducted. 20 non-expert viewers were asked to give their opinion about quality. Bubble sort method explained in [7] was used for this purpose.

Correlation coefficient between subjective and objective test was calculated.

IV. RESULTS

Blur and ringing is measured for three types of compression schemes, i.e. JPEG (DCT based) SPIHT (wavelet transform based) and simple uniform scalar quantization in wavelet domain. Compression ratio was changed to create different images. Total blur and ringing was compared with subjective tests taken. Smaller the subjective value of blur or ringing, it indicates less amount of artifact effect. Also smaller objective value of blur or ringing metric means smaller blur or ringing effect.

TABLE I
 CORRELATION IN DIFFERENT BANDS

LL3	LH3	HL3	HH3	LH2	HL2	HH2	LH1	HL1	HH1
.0014	.386	.147	.197	.378	.19	.214	.40	.73	.258

TABLE II
 CORRELATION IN DIFFERENT WAVELET BANDS FOR DIFFERENT COMPRESSION SCHEMES

Type	Image	Correlation									
		LL3	LH3	HL3	HH3	LH2	HL2	HH2	LH1	HL1	HH1
JPEG(DCT)	Testb1	0	.378	.143	.186	.375	.196	.126	.356	.447	.312
	Testb3	.0010	.385	.148	.197	.376	.199	.218	.40	.66	.20
	Testb2	.0016	.386	.145	.197	.376	.200	.215	.41	.607	.286
SPIHT	Tests1	.002	.386	.164	.159	.080	.029	.017	.176	.83	.0016
	Tests2	.002	.376	.159	.196	.348	.263	.083	.213	.824	.038
	Tests3	.002	.385	.153	.206	.376	.22	.166	.242	.80	.107
Scalar quantized	Testpats1	.0016	.146	.037	.196	.112	.04	.104	.0012	.109	.0004
	Testpats2	.008	.378	.144	.187	.297	.217	.172	.029	.707	.179
	Testpats6	.0012	.386	.145	.196	.376	.196	.212	.39	.699	.194

TABLE III
 OBJECTIVE AND SUBJECTIVE BLUR

Image	Edge	Blur	Subjective blur	Subjective edge
Testb1	.5	.0625	6	7
Testb2	.129	.0585	6	2
Testb3	.133	.020	2	2
Tests1	.998	.035	7	9
Tests2	.65	.224	6	8
Tests3	.361	.143	5	5
Testpats1	2.67	.045	5	18
Testpats2	.65	.04	3	8
Testpats6	.117	.0085	2	2

V. CONCLUSION

Correlation between subjective blur artifact and objective blur artifact is **0.94**

Correlation between subjective ringing artifact and objective ringing artifact is **0.945**.

The new measure shows good correlation with subjective blur and edge artifact rating. It gives numeric value of artifact error, therefore more exactness compared to other methods. It is easy to compare quality of two images using these two measures.

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