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Structural Similarity Based Image Quality Assessment Using Full Reference Method

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Abstract: This paper presents an objective quality assessment for digital images that have been degraded by noise. Objective quality assessment is crucial and is generally used in image processing. The main objective of this paper is to analyse various statistical properties and their measurements and finally compare them. The statistical properties that are included are mean square error (MSE), root mean square error (RMSE), signal to noise ratio (SNRQ), peak signal to noise ratio (PSNR) and certain frequency parameters like spectral magnitude distortions and spectral phase distortions. But it is observed that MSE and PSNR yield poor results therefore a new metric namely structure similarity is proposed which has a better performance than MSE and PSNR but fails when applied on badly blurred images. Therefore, edge based structure similarity index metric (ESSIM) is proposed. Experiment results show that ESSIM is more consistent with human visual system (HVS) than SSIM and PSNR especially for the blurred images.

Keywords— Edge based structural similarity index metric (ESSIM), human visual system (HVS), mean square error (MSE), peak signal to noise ratio (PSNR), root mean square error (RMSE), signal to noise ratio (SNRQ), structure similarity index metric (SSIM)

I. INTRODUCTION

Image quality assessment plays a vital role in diverse image processing applications. The existing image quality evaluation methods can be categorized into subjective evaluation and objective evaluation. The most accurate method of quantifying image quality is through subjective evaluation. But subjective evaluation requires gathering the observers to mark the distorted images, which is a time-consuming, expensive and an inconvenient task. Therefore, the objective evaluation is used which is most consistent with the human visual system (HVS) [1].The objective image quality metrics can be categorized into three types according to the accessibility of an original or a distortion-less image, with which the distorted image is to be compared. Firstly full-reference in which the original or distortion-less image is assumed to be known. Secondly, a no-reference or "blind" quality assessment approach in which the original image is not available for comparison with the distorted image. Lastly, the reduced-reference quality assessment in which the original image is partially available for reference as a set of extracted features. This paper mainly focuses on full-reference image quality assessment [2].

The PSNR and MSE are generally the most widely used full reference objective metric as they have a very low complexity and a clear physical meaning. But these parameters do not have a good correlation with the HVS [2]. Therefore, SSIM is used that compares local patterns of pixel intensities that are normalized for contrast and luminance. SSIM shows a better consistency with the human visual system than MSE and PSNR but it fails when applied on badly blurred images. Therefore, ESSIM is used which is more consistent with HVS for badly distorted images when compared with MSE, PSNR and SSIM [3].

II. OBJECTIVE EVALUATION METHODS

Two types of objective evaluation methods has been explained below namely full reference and no reference evaluation methods.

A. Full Reference

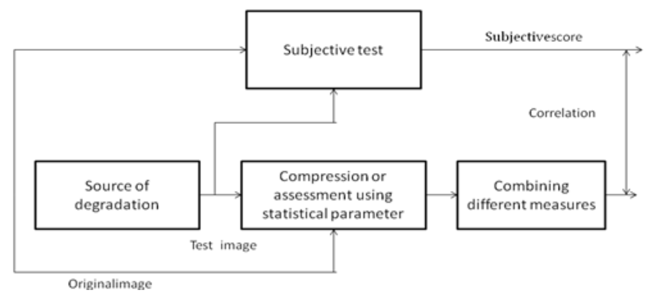

Fig 1 (a) Block diagram using reference image

While detecting the images, the reference image of the image which needs to be examined is already present. This technique is therefore known as “full reference” detection. As shown in the block diagram, the original image is passed and there is some source of degradation. So the two images, the original and the corrupted are present. Now using some statistical properties such as Mean Square Error, PSNR etc. and also doing the subjective tests we will find the correlation between two images. After that combining all the measures, the amount of degradation such as blurriness, blockiness etc. can be found out. As the reference image is present, the distorted image is compared with the reference therefore getting the exact amount of degradation value.

B. No Reference

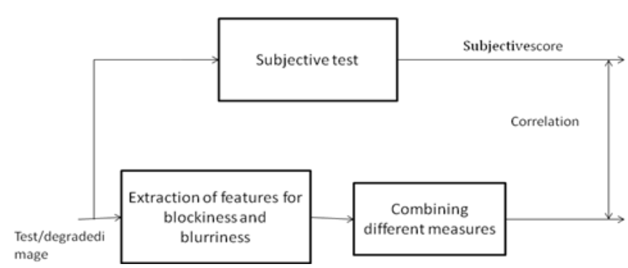

Fig 1 (b) Block diagram without reference image

In case of the images which are not having any reference image the detection will be without reference. We get the image directly from the sources like internet and we have to find its degradation that is amount of distortion and also have to do subjective tests. Then combining all the results we can find out the amount of degradation.

III. IMAGE QUALITY MEASURES

The following are the statistical properties that have been measured, evaluated and analysed for the distorted digital images [4]-

1. *Mean Square Error(MSE)*

Let f(x,y) be the original image, f'(x,y) be approximation of f(x,y) that results from compressing and decompressing original image. For any value of x and y, the error e(x,y) between f(x,y) and f'(x,y) is given by e(x,y)=f(x,y)-f'(x,y). So the total error between two images e(x, y)=∑∑f(x,y)-f'(x,y), where the images are of size MxN. The mean square error (MSE), between f(x, y) and f'(x,y) is then the squared error averaged over the MxN array given by -

$$\mathrm{MSE} = \frac{1}{MN}\sum_{x=1}^{M}\sum_{y=1}^{N}[f'(x,y) - f(x,y)]^2 \quad ....(1)$$

2. *Root Mean Square Error(RMSE)*

If f'(x,y) is considered to be the sum of the original image f(x,y) and an error or "noise" signal e(x,y) the root-mean-square-error (RMSE), between f(x,y) and f'(x,y) is the square root of the squared error averaged over the MxN array given by :-

$$\mathrm{RMSE} = [\frac{1}{MXN}\sum_{X=1}^{M}\sum_{Y=1}^{N}[f' - f(x,y)]^2]^{\frac{1}{2}} \quad .... (2)$$

3. *Signal to Noise Ratio(SNRQ)*

Signal to noise ratio measures quality of an image and it is given by-

$$\mathrm{SNRms} = \frac{[\sum_{x=1}^{M}\sum_{y=1}^{N} f'(x,y)]^2}{[\sum_{x=1}^{M}\sum_{y=1}^{N}[f'(x,y) - f(x,y)]]^2} \quad .... (3)$$

4. *Peak Signal to Noise Ratio(PSNR)*

Peak signal to noise ratio is given by -

$$\mathrm{PSNR} = \frac{[10\log(\mathrm{Lmax})^2]}{\mathrm{MSE}} \quad .... (4)$$

Where, Lmax=max length

i.e.

$$L_{max} = [(2^n) - 1] \quad .... (5)$$

Where, n= no of bits per pixel;(2^n)= no of gray levels

IV. STRUCTURE SIMILARITY BASED IMAGE QUALITY ASSESSMENT

Structural similarity (SSIM) is a novel image quality assessment method and attracts a lot of attention for its god performance and simple calculation. This metric has better performance than PSNR in many cases but fails in case evaluating badly blurred images [3].SSIM is given as –

$$\mathrm{SSIM}(x,y)=f(I(x,y),c(x,y),s(x,y)) \quad ….(6)$$

Where,

I(x,y) = Luminance comparison
c(x,y) = Contrast comparison
s(x,y) = Structure comparison

Mean Intensity:

$$\mu_x = \frac{1}{N}\sum_{i=1}^{N} x_i \quad ….(7)$$

Standard deviation:

$$\sigma_x = (\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \mu_x)^2)^{\frac{1}{2}} \quad .... (8)$$

Contrast comparison c(x,y) - difference of σ_x and σ_y,

$$c(x,y) = \frac{2\sigma_x\sigma_y + c_2}{\sigma^2_x + \sigma^2_y + c_2} \quad .... (9)$$

Luminance comparison,

$$l(x,y) = \frac{2\mu_x\mu_y + c_1}{\mu^2_x + \mu^2_y + c_1} \quad ....(10)$$

C1, C2 are constants and the structure comparison (s(x,y)) is conducted on these normalized signals (x- μ_x)/σ_x and(y- μ_y)/ σ_y.

$$S(x,y) = f(l(x,y), c(x,y), s(x,y)) \quad ….(11)$$

$$\mathrm{SSIM}(x,y) = [l(x,y)]^{\alpha}.[c(x,y)]^{\beta}.[s(x,y)]^{\gamma} \quad ….(12)$$

$$\mathrm{SSIM}(x,y) = \frac{(2\mu_x\mu_y + C_1)(2\sigma_{xy} + C_2)}{(\mu^2_x + \mu^2_y + C_1)(\sigma^2_x + \sigma^2_y + C_2)} \quad ….(13)$$

C1 and C2 are constant we have consider them as zero and α, β and γ are parameters used to adjust the relative importance of the three components.

V. EDGE BASED STRUCTURAL SIMILARITY

Edge-based structural similarity (*ESSIM*) compares the edge information between the original and the distorted image block and replaces the structure comparison *s*(***x***,***y***) in equation (14) by the edge-based structure comparison *e*(***x***,***y***) [1].

There are a numerous ways to extract the edge information but in this paper we will be using the Sobel masks as it is simple to apply and is efficient at the same time [5].

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-1	0	+1
-2	0	+2
-1	0	+1

Vertical edge mask

-1	-2	-1
0	0	0
+1	+2	+1

Horizontal edge mask

Fig .2 Sobel Operator Masks

These, Sobel masks are applied on the distorted digital image to get $dx_{i,j}$ and $dy_{i,j}$. The edge vector can then be represented as its amplitude and direction given by:-

$$Amp_{i,j} = |dx_{i,j}| + |dy_{i,j}| \quad ....(14)$$

$$Ang_{i,j} = \frac{180}{\pi} \times \arctan\left(\frac{dy_{i,j}}{dx_{i,j}}\right) \quad ....(15)$$

If Dx and D_y represent the original image block edge direction vector and the distorted one then the edge comparison *e*(x,y) is obtained by calculating the correlation coefficient of Dx and D_y , that is –

$$e(x,y) = \frac{\sigma_{xy} + c_3}{\sigma_x \sigma_y + c_3} \quad ....(16)$$

The rest of the equations are analogous to the structural similarity index metric (SSIM).

VI. RESULTS


Fig .3 Original Image


Fig .4 Quality10


Fig .5 Quality 30

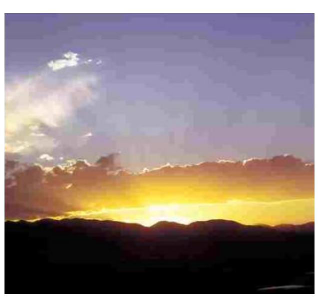
Fig .6 Quality50


Fig .7 Quality70


Fig .8 Original Image


Fig .9 Quality10


Fig .10 Quality 30

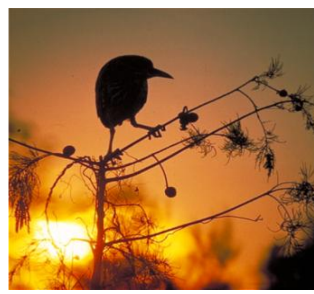
Fig .11 Quality50

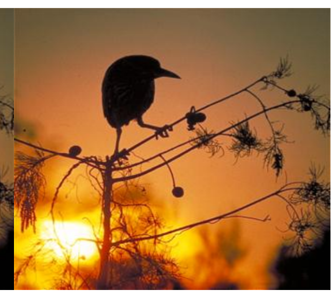
Fig .12 Quality70


Fig .13 quality50


Fig .14 quality70


Fig .15 MASK13x13


Fig .16 MASK17x17

Figure No	MSE	PSNR	RMSE	SNRQ	SSIM	ESSIM
4	7.07E-005	206.4680	0.0084	13.2162	0.1696	0.1650
5	3.75E-005	212.7899	0.0061	19.5381	0.4539	0.4409
6	1.86E-005	219.8092	0.0043	26.5575	0.7751	0.7482
7	5.63E-005	231.7714	0.0024	38.5197	0.8556	0.8316
9	7.78E-005	205.5141	0.0088	13.1760	0.0287	0.0206
10	4.11E-005	211.8818	0.0064	19.5437	0.2581	0.1969
11	1.51E-005	221.8891	0.0039	29.5510	0.7871	0.6788
12	5.92E-006	231.2596	0.0024	38.9215	0.9137	0.8582

Table 1 Various Statistical Properties for Degraded Image

Figure No	MSE	SSIM
13	7.90E-06	0.9992
14	5.24E-06	0.9994
15	1.59E-04	0.9492
16	1.84E-04	0.937

Table 2 Comparisons of MSE and SSIM for Degraded Images

Figure No	SSIM	ESSIM
17	0.5693	0.5401
18	0.7960	0.6809

Table 3 Comparisons of SSIM and ESSIM for Degraded Images

Fig(3) is the original image of a sunset. Figs (4) to Fig (7) have been distorted by various degrees of blockiness artefacts with Fig (7) having the best quality and Fig (4) the worst. The table 1 show that the best quality image has the highest SNRQ and PSNR but the lowest MSE and RMSE. It also has values of SSIM and ESSIM close to 1 indicating that it is very close to the original image. Whereas, Fig (4) has the value of SSIM and ESSIM close to 0 indicating that it has lots of distortions and it is not at all close to the original image.

Fig (8) is the original image of a sunset. Figs (9) to Fig (12) have been distorted by various degrees of blockiness artefacts with Fig (12) having the best quality and Fig (9) the worst. The table 1 show that the best quality image has the highest SNRQ and PSNR but the lowest MSE and RMSE. It also has values of SSIM and ESSIM close to 1 indicating that it is very close to the original image. Whereas, Fig (9) has the value of SSIM and ESSIM close to 0 indicating that it has lots of distortions and it is not at all close to the original image.

The table 2 shows the comparison between the performance of MSE and SSIM. If the values in table 2 are compared, Fig (15) is more distorted than Fig (13).But the MSE for Fig (15) is less than MSE of Fig (13), which is improper. While SSIM is giving correct result and outperforms MSE.

From the table 3 we can conclude that the performance of ESSIM is better than that of SSIM in case of badly blurred images as the values of ESSIM is lesser than that of SSIM therefore implying that the pixel values of the digital image have been distorted.

VII. CONCLUSIONS

In this paper, various algorithms of different statistical parameters such as MSE, PSNR, SNRQ, RMSE, SSIM and ESSIM have been successfully implemented. We have also concluded that SSIM is better than other statistical parameters like MSE and PSNR from the experimental results. Also it can be concluded from the results that the drawback of SSIM is overcome by ESSIM. Therefore, ESSIM is the objective evaluation method which is the most consistent with the human visual system (HVS).

REFERENCES

i. *Guan-Hao Chen, Chun-Ling Yang, Lai-Man Po and Sheng-Li Xie, " Edge based structural similarity for image quality assessment", Department of Electronic Engineering, City University of Hong Kong*

ii. *Zhou Wang, Alan Conrad Bovik, Hamid Rahim Sheikh, and Eero P Simoncelli, Senior Member, "Image quality assessment: From error visibility to structural similarity", IEEE transactions on image processing, Vol. 13, No.4, April 2004*

iii. *Bo Wang, Zhibing Wang, Yupeng Liao, Xinggang Lin, "HVS based structural similarity for image quality assessment", ICSP 2008 proceedings*

iv. *Ahmet M. Eskicioglu, Paul S Fisher, " Image quality measures and their performance", IEEE transactions on communications, vol. 43, no. 12, December 1995*

v. *Rafael C. Gonzalez and Richard E. Woods, "Digital image Processing", (Third edition)*