MSE Vs SSIM

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Abstract—IQA plays important role in digital image processing. It can be used to improve pictorial information or processing of data for transmission and representation. It can be done using FR,RR and NR methods depending on the availability of original and test image. In this paper concentrating on FR IQA methods using SSIM.

Index Terms— Digital image processing, Image Quality Assessment (IQA),Mean Square Error (MSE),Structural Similarity Index Matrices (MSE). .

1.INTRODUCTION :

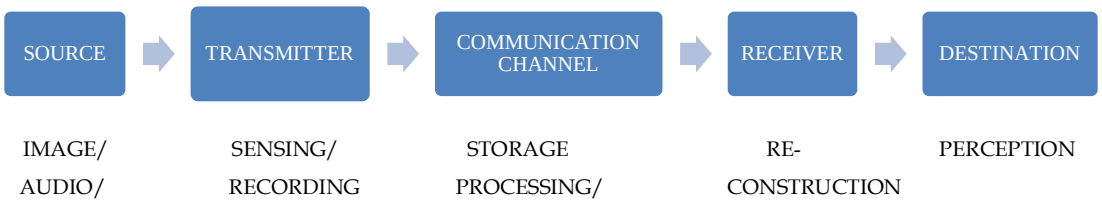

Fig.1 Basic Digital Image Processing System.

Digital image processing methods are used for two basic principal applications, such as first for improvement of pictorial information for human perception and second for processing of image data for storage, transmission and representation for autonomous machine perception.

An image may be defined as two dimensional function f(x,y) where x and y are spatial coordinates and amplitude of f at any pair of coordinate (x,y) is called the intensity or gray level of image at that point when x, y and amplitude value of f are all finite value, is called as digital image. Digital image composed of finite number of elements where each have particular location and value called pixels.As shown in fig.(1), overall digital image processing is divided into three levels such as low level, medium level and high level of processing.

Low level processing involves source and transmitter. Source is nothing but image, audio or video .here we consider digital image only. At the transmitter side, preprocessing is done after sensing the object. Preprocessing involves primary operations such as noise reduction, contrast enhancement and image sharpening.

Medium level processing is done at communication channel.

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At this level, segmentation, storage and transmission is done on input image. Hence output from medium level processing is nothing but extracted features such as edges, lines, curves and identity of individual object. Finally higher level processing is on receiver side. Receiver reconstruct the information and on that basis reorganization or perception is done.

During all this ,image quality which is received at the end side get degraded. Human being are the good observer who can analyse image quality using principle of perception of vision. Image quality can be defined in terms of image fidelity that is perfect image. Image quality is degree to which image satisfy the naturalness and usefulness of image. Hence, image quality assessment plays important role in variety of applications. It can be used to in acquisition and display system to monitor image quality. It can be used as benchmarking in different compression algorithm.

2 IMAGE QUALITY ASSESSMENT METHODS:

Image quality assessment methods (IQA) can be widely done using two methods namely subjective method and objective method asshown in fig.(2). In subjective analysis, group of observers are present to analyse the perceived image quality. Then overall quality score is calculated using mean

opinion score(MOS) and differential mean opinion score (DMOS) is calculated. On that basis, quantitative analysis of image is done. Some criteria are consider during analysis such as viewing distance, angle, period, background and knowledge about image processing. Though it is more accurate for evaluating quality of perceived image still it is complicated and time consuming.

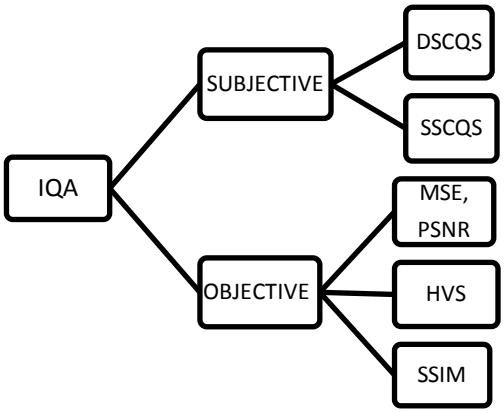

Fig.2: Image Quality Assessment Methods

In objective analysis is done for automatically evaluate the quality matrices using mathematical calculation. Depending on availability of reference image, it can be classified into full reference FR, reduced reference RR and no/blind reference NR IQA.

- Full Reference (FR) IQA-Both test and original images are present.
- No Reference(NR) IQA-Only test image is present.
- Reduced Reference(RR) IQA-Partial information is available.(A set of extracted features made available.)

Most o f IQA methods are derived using full reference method. Here ,SSIM based full reference IQA is explained

3.MEAN SQUARE ERROR (MSE):

Traditional and simple method for measuring the energy of error signal in test image. square of difference between error of original and test /distorted image is calculated.
Two signals are compared pixel by pixel from left to right and top to bottom through a row and column. Then calculate by averaging square of difference between error of original and test /distorted image.
If x and y are two non negative gray scale images, the1n MSE is calculated using

$$\text{MSE}=\frac{1}{\text{N}}\sum_{i=1}^{N}|x_i - y_i|^2 \qquad (1)$$

Peak signal to noise ratio is calculated as follow,

$$\text{PSNR}=10\ log_{10}\left(\frac{m^2}{\text{MSE}}\right)\ db. \qquad (2)$$

where m are maximum gray levels of 8 bits/pixel of image.(Here, m=100 considered otherwise m=255 for 8 bits/pixel) .

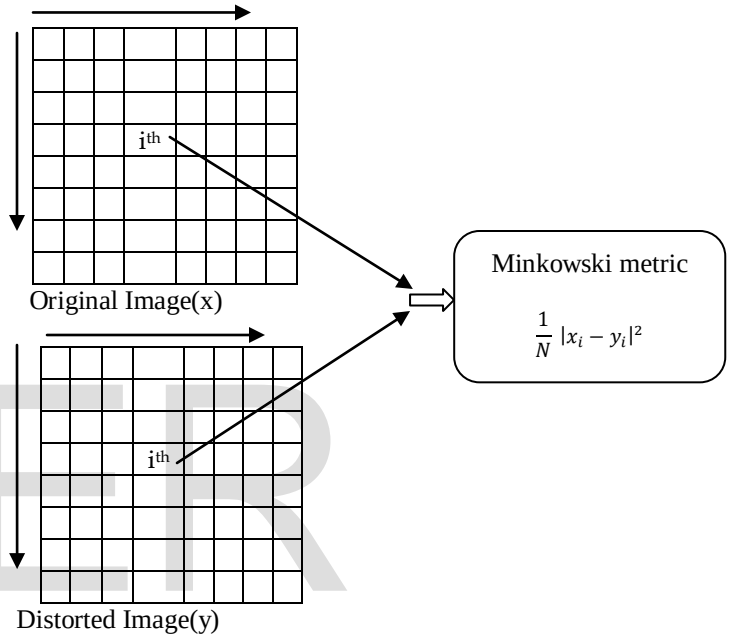

Fig.3: Minkowski Metric For calculating MSE

Two signals are compared pixel by pixel from left to right and top to bottom through a row and column. Then calculate by averaging square of difference between error of original and test /distorted image.

3.1 PROPERTIES:

[1] simple and parameter independent.
[2] Square error calculated ,is independent of other sample.
[3] MSE ≥ 0.
[4] MSE = 0 iff original signal(x)=test signal(y).
[5] Clear physical meaning.

MSE value is small or equal to zero, indicate minimum or zero distortion.MSE widely used in variety of signal processing applications such as denoising, reconstruction, classification, restoration, filter designing.

3.2 DISADVANTAGES:

- Major disadvantage of MSE is poorly correlate with human perception of visual system.
- According to human visual system HVS, error visibility is correlate with loss of quality. But ,MSE totally mismatch with this because some distortions are not clearly visible and some are present but not disturbing the image quality.
- All images with equal MSE, does not mean that all contain same distortions or noise.

4.STRUCTURAL SIMILARITY INDEX MATRICES(SSIM):

A new approach proposed to overcome this problem which provide solutions which are independent of visibility conditions and threshold problems. Main aim to extract structural information from image. Structural Similarity Index Matrix (SSIM) separate out the three parameter such as luminance, contrast and structure which are independent of each other and are highly structured.

If consider two non negative images x and y where x is original discrete signal and y is distorted discrete signal, then

SSIM(x,y)=f[l(x,y),c(x,y),s(x,y)] (3)

luminance l(x,y) is given by

$$l(x,y)=\frac{(2\mu_x\mu_y+C1)}{(\mu_x{}^2+\mu_y{}^2+C1)} \quad (4)$$

where original signal mean intensity $\mu_x=\frac{1}{N}\sum_{i=1}^{N}x_i$, distorted signal mean intensity $\mu_y=\frac{1}{N}\sum_{i=1}^{N}y_i$ and C1 is constant added to avoid instability when $(\mu_x{}^2+\mu_y{}^2)$ is very close to zero and equal to $(K_1 l)^2$. l is dynamic range of pixel values (255 for 8 bit gray scale image) and $K_1 \ll 1$.

According to Webbers law, the magnitude of just noticeable luminance change ΔI is approximately proportional to background luminance I for wide range of luminance values. Let R is change relative to background luminance, we rewrite luminance of distorted signal as

$$\mu_y = (1+R)\,\mu_x. \quad (5)$$

Substituting in above equation(4),

$$l(x,y)=\frac{2(1+R)}{1+(1+R^2+\frac{C1}{\mu_x{}^2})} \quad (6)$$

If we assume C1 is small enough compare to $\mu_x{}^2$,then above equation is function of only R and consistent with webbers law.

Contrast c(x,y) is given by

$$c(x,y)=\frac{(2\sigma_x\sigma_y+C2)}{(\sigma_x{}^2+\sigma_y{}^2+C2)} \quad (7)$$

where σ_x , standard deviation as an estimate of signal contrast by subtracting mean intensity from signal.

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

C2=$(K_2 l)2$ and $K_2 \ll 1$ as small count.

With same amount of contrast change $\Delta\sigma = \sigma_y - \sigma_x$, this is less sensitive to high base contrast $\sigma_x$than low base contrast proves contrast masking feature in human visual system(HVS).

Structure is calculated after subtracting luminance and variance normalization, we associate with two unit vectors given by $\frac{(x-\mu_x)}{\sigma_x}$ and $\frac{(y-\mu_y)}{\sigma_y}$.Structure s(x,y) is calculated as follows:

$$s(x,y)=\frac{\sigma_{xy}+C3}{\sigma_x\sigma_y+C3} \quad (9)$$

where C3 is small constant and

$$\sigma_{xy}=\frac{1}{N-1}\sum_{i=1}^{N}(x_i-\mu_x)(y_i-\mu_y) \quad (10)$$

Hence, resultant SSIM(x,y) index is given by

$$SSIM(x,y)=\frac{(2\mu_x\mu_y+C1)(2\sigma_x\sigma_y+C2)}{(\mu_x{}^2+\mu_y{}^2+C1)(\sigma_x{}^2+\sigma_y{}^2+C2)} \quad (11)$$

where all three parameters are highly structured and relatively independent.

Mean SSIM (MSSIM) is calculated to evaluate overall image quality is given by

$$MSSIM(x,y)=\frac{1}{M}\sum_{j=1}^{M}SSIM(x_j,y_j) \quad (11)$$

4.1 PROPERTIES OF SSIM:

- Symmetry , S(x,y)=S(y,x)
- Unique maximum, S(x,y)=1 iff x=y
- Boundedness, S(x.y)≤ 1

5. EXPERIMENTAL RESULTS:

A original image of harbour is taken, which is distorted with 4 different types of distortion

such as blurring,gaussian noise,JPG and JPG2K . All distorted images set with equal value of MSE. SSIM and error map is calculated for these distorted image along with original image.It proves that the matrices calculated is independent of visibility of error.

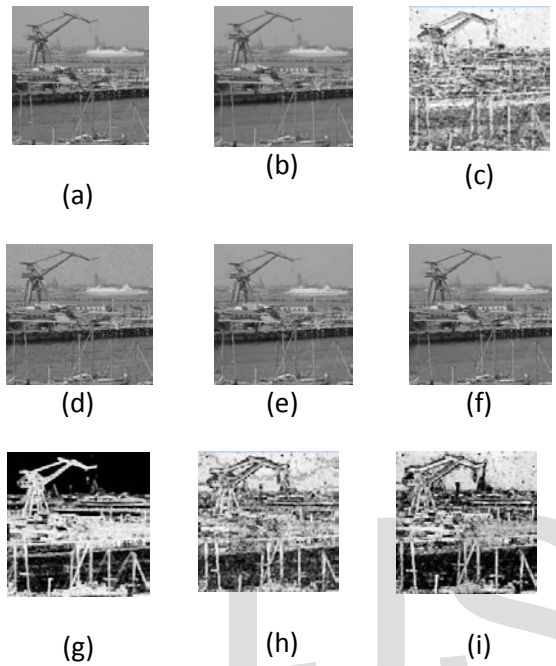

Fig. 4.Comparision of "harbor" images with different types of distortions and their SSIM error map. a)Original image, MSE=0;PSNR=INF;MSSIM=1;b)Blurr image;MSE=83.61;PSNR=27.93; MSSIM=0.909; d) Noisy image;MSE=87.23;PSNR=28.68; MSSIM=0.734; e)JPG image;MSE=83.58;PSNR=28.90; MSSIM=0.877; f) JPG2 image;MSE=85.88;PSNR=28.79; MSSIM=0.834; c),g),h) andi)SSIM error map of Blurr image, Noisy image,JPG image and JPG2 repectively.

CONCLUSION:

Most of digital image processing application where IQA plays important role. SSIM totally depends on structural features which are extracted from image. Luminance. contrast and structure ,all parameters are independent. SSIM error map shows area which is more affected by noise. Hence it is easy to reconstruct the distorted image .

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