

Method of image quality assessment based on region of interest and Structural Similarity

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Abstract. In this paper, a method of image quality assessment based on visual regions of interest and Structural Similarity(SSIM) is proposed through combining human visual interest regions and structural similarity. In this algorithm, we firstly use the SSIM to separately assess those interest regions, and get weight of different regions through analyzing the influencing factors such as brightness, gray level, area size, and then work out the image quality of ROI by adding up those weights of different regions. Secondly we can get the assessment of the entire image by using the SSIM to evaluate the entire image. The final assessment of image is the result of adding up different weights of the entire image and ROI. What's more, the experiment results prove the method is more accurate and efficient than SSIM.

Introduction

With the development of image processing technology, it has great significance that how to more effectively assess an image, so as to provide reference for adjusting the image quality, optimizing algorithm and detection system. At present, there are two image assessment methods: subjective and objective. The subjective assessment regards subjective visual as the assessment criterion and depends on the observer to assess image quality; The objective assessment is a quantitative description of image quality by means of mathematical model, statistical analysis and so on. According to the level of dependence on the original image, the objective assessment is divided into three categories: full reference, weak reference and No-Reference. ① Full Reference QA, assess image through the method of compare the original and evaluated image; ② Weak reference QA, it use some characteristic information obtained from the reference image to evaluate image quality; ③ No-reference QA^[1], it evaluates the image with no reference.

In the two methods, the subjective assessment needs special training for the personnel, and its process is time-consuming and money-wasting. Moreover, it cannot be used in real-time assessment because of it depends on the man's subjective vision. The full reference and weak reference assessment all depends on the reference image, while in some applications, the original image is often difficult or even impossible to achieve. Therefore, it weighs more important to study the No-Reference image quality assessment.

In the No-Reference quality assessment system, most of methods aim at the whole image, without considering observers quality requirements in different regions, so that some image assessment result do not match the subjective assessment. This essay is based on Structural Similarity definition algorithm and proposes an assessment method comprehensively considering the quality of whole image and Region-Of-Interest. Experimental results show that this method is consistent with subjective assessment results not only for the quality of whole image but also for partly-blur image^[2].

Method of image quality assessment based on Region-Of-Interest

Due to the human physiological characteristics, people can only observe seriously one region of a picture and cannot identify other areas. Some research shows that when people observe a thing seriously, the visual effective area is only coin size. Meantime, human visual system has local contrast sensitivity that vision is only interested in a region of significant changes in the visual field. So people in the image observation will form a "Region-Of-Interest"^[3].

The method of image quality assessment based on Region-Of-Interest combines the human eye selectivity and the objective assessment method, which takes full consideration on visual characteristics in order to make the assessment result conform to subjective feeling.

Literature [4] introduced an improvement of the Mean Square Error (MSE) and Peak Signal-to-Noise Ratio (PSNR) used to evaluate the Region-Of-Interest.

$$HMSE = \frac{\sum_{i=1}^N p_i \sum_{A_i} [f(m,n) - f'(m,n)]^2 + p'_i \sum_{A_L} [f(m,n) - f'(m,n)]^2}{\sum_{A-A_i} [f(m,n) - f'(m,n)]^2}. \quad (1)$$

$$HPSNR = 10 \lg \frac{256 \times 256}{HMSE}. \quad (2)$$

Notes: A_i ($i=1,2,\dots,N$) stands for the Region-Of-Interest. S_i ($i=1,2,\dots,N$) is the area size of A_i ; A_L is the rest area. S means the total area of the image. The weighted coefficient of the interested is p_i ($i=1,2,\dots,N$); the weighted coefficient of the non-interested region is p'_i .

Reblur Theory

In the image frequency domain analysis, it can be known that the image clarity has nothing to do with the low frequency component, decided only by the middle or high frequency component of the energy. Therefore, when the middle or high frequency components are filtered by a low pass filter, the image will become blurred. For a fuzzy image, the middle or high frequency components of the image are relatively small, so a low pass filter has little effect on the image quality. For the clear image, the low pass filter will make it lose the middle or high frequency component, thus the image quality will be poor. Based on this, the change of adjacent pixel values of two images before and after filtering can be compared to measure the clarity^[5,6].

Structural Similarities

The reference[7- 10] proposed that the structural distortion is the key factor in the image quality assessment, and pointed out the Structural Similarity theory and Structural Similarity Index Measurement(SSIM). SSIM is divided the image into three parts:lightness, contract and structure. They are separately compared, then the weighted product to work out the SSIM value.

$$SSIM(x, y) = [l(x, y)]^a [c(x, y)]^b [s(x, y)]^g. \quad (3)$$

$$\begin{cases} l(x, y) = \frac{2u_x u_y + c_1}{u_x^2 + u_y^2 + c_1} \\ c(x, y) = \frac{2s_x s_y + c_2}{s_x^2 + s_y^2 + c_2} \\ s(x, y) = \frac{s_{xy} + c_3}{s_x s_y + c_3} \end{cases}. \quad (4)$$

Note: u_x, u_y as the average lightness of the reference image and evaluated image, σ_x, σ_y , as standard deviation, σ_{xy} is the covariance. c_1, c_2, c_3 as the constant. When $a = b = g, c_3 = c_2 / 2$, Eq. (4) can be simplified as:

$$SSIM = \frac{(2u_x u_y + c_1)(2s_{xy} + c_2)}{(u_x^2 + u_y^2 + c_1)(s_x^2 + s_y^2 + c_2)}. \quad (5)$$

SSIM has better effect on static image quality assessment, but for overall badly blurred image, the local blur quality but wholly acceptable image, and local blur image, the effect is not ideal but very inconsistent with subjective feeling^[8].

Method of image quality assessment based on Region-Of-Interest and Structural Similarity

The assessment method is shown in Fig.1:

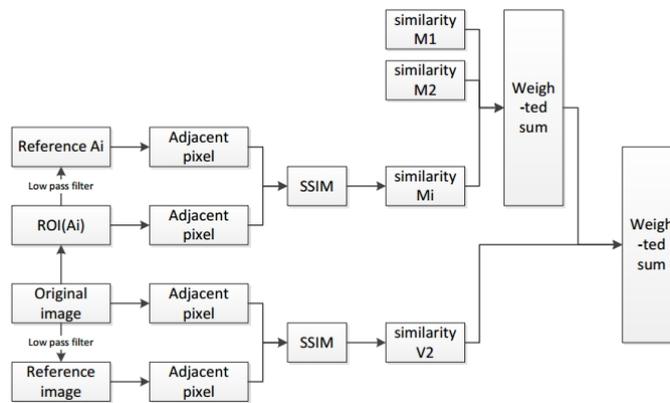


Fig.1 the steps of assessment method

In view of the reblur theory and Structural Similarity principle, this paper proposed a method of image assessment based on the Structural Similarity of the visual interest region by considering the overall quality of the image and the visual characteristics of the human eye. The assessment method is divided into two parts: the Region-Of-Interest and the overall image assessment. The specific process is as follows:

ROI(Region-Of-Interest) assessment. ROI assessment is the assessment of the possible interest regions in the image. Assume that the image has N regions A_i ($i=1,2,\dots,N$), the area is S_i ($i=1,2,\dots,N$). By low pass filtering A_i , the reference image of A_i is obtained. Then compare the Structural Similarity M_i of the two structures and weight sum of M_i , Finally the weighted coefficient p_i is determined by the intensity, area size and gray level:

(1) The influence of brightness on interest

$$s_i = k \left| \lg \frac{I_i}{I_{oi}} \right|. \quad (6)$$

Note: I_i is the brightness of ROI area A_i , I_{oi} is background brightness, s_i is the weighted coefficient caused by brightness;

(2) The influence of area on interest

$$t_i = j \lg \frac{\sqrt{s}}{\sqrt{s} - s_i}. \quad (7)$$

Note: s is the area of the full image, s_i is the area of the ROI, t_i is the weighted coefficient caused by area;

(3) The influence of gray on interest

$$w_i = h \lg \frac{r_i}{r_{oi}} . \quad (8)$$

Note: r_i is the average gray of the boundary of ROI, r_{oi} is the average gray of the adjacent outside the boundary, w_i is the weighted coefficient caused by gray;

Weight p_i :

$$p_i = \sqrt{s_i^2 + t_i^2 + w_i^2} . \quad (9)$$

(4) The assessment of ROI area V_1 :

$$V_1 = \sum_{i=1}^N p_i \times M_i . \quad (10)$$

Whole image assessment. Whole image assessment is a comprehensive assessment of the whole image. First by low-pass filtering of the evaluated image to calculate the image structure similarity V_2 , and weighting sum the value V_1 and the full image assessment value V_2 , the comprehensive assessment of the evaluated image will appear.

$$blur = a \times V_1 + b \times V_2 . \quad (11)$$

$$RSSIM = 1 - blur . \quad (12)$$

Experimental verification. This paper adopts the Release Database 2 image database of University of Texas-Austin^[11] to verify the assessment method. From the image database, we choose a set of images with different blur degree. Then respectively use a simple SSIM assessment method and the assessment method based on the Structural Similarity of the interest region, the part assessment results are shown in Figure 1. Experimental results from comparing results of the two assessment methods and the blur degree relationship to the image provided in the image database are shown in table 1.



Fig.a

Fig.b

Fig. c

Fig. d

Table 1 the experimental data

Image	a	b	c	d	e	f
blur	0	0.562467	0.848926	1.450490	1.708303	2.510388
SSIM	0.0829	0.054	0.0324	0.0118	0.081	0.031
RSSIM	0.4442	0.4262	0.4126	0.4001	0.3979	0.3951

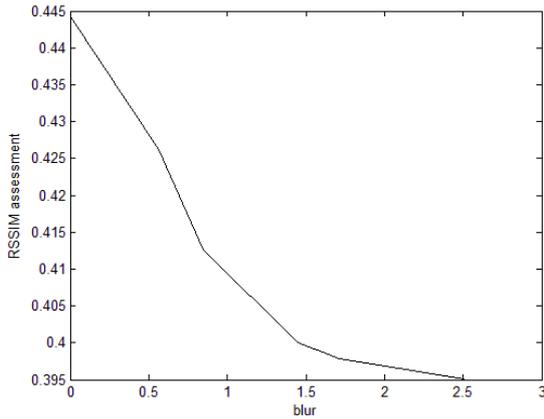


Fig.2 RSSIM assessment

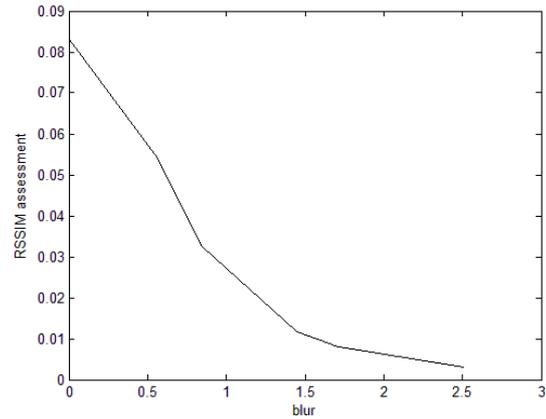


Fig.3 SSIM assessment

Figure 2 and Figure 3 show the relationship between SSIM and RSSIM and the given blur image in the image database. From the table 1 and figures. The effect of RSSIM image quality assessment method and SSIM assessment are not big difference. In a low degree of blur, the sensitivity of the RSSIM is higher than SSIM, while in the higher part, RSSIM sensitivity is lower. In some way, it is better to assess the serious blur image.

In order to verify the effect for local blur but whole acceptable images through the method of image quality assessment based on Region-Of-Interest and Structural Similarity (RSSIM). This paper uses the Gaussian blur to filter a small region of the original image. Some different degrees of blur image are partly shown in Figure followed. Then, the local blur image is evaluated by SSIM and RSSIM respectively, and the assessment value of the two are compared. Experimental data are shown in table 2.



Fig.e

Fig.f

Fig.g

Fig.h

Table 2 the part blur experiment data

image	e	f	g	h	i	j
blur	3×3	4×4	5×5	6×6	7×7	8×8
SSIM	0.0717	0.0703	0.0695	0.0697	0.0690	0.0690
RSSIM	0.4293	0.4285	0.4281	0.4279	0.4278	0.4277

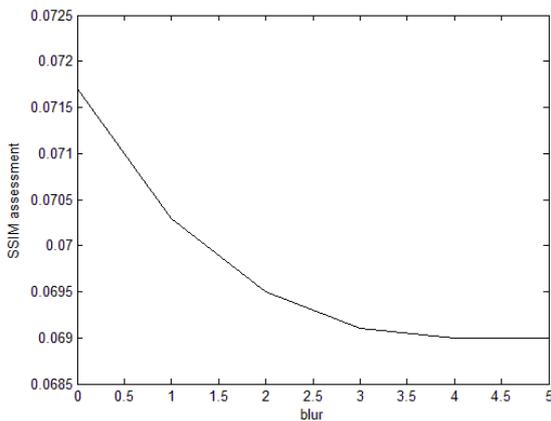


Figure 4. SSIM assessment for locality blur

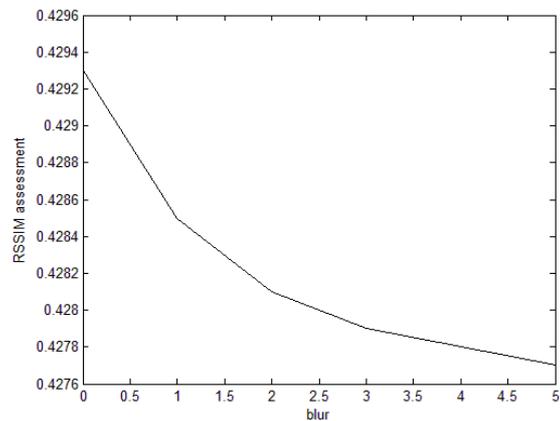


Figure 5. RSSIM assessment for locality blur

From figure 4 and figure 5 of the whole acceptable but local blur image assessment, RSSIM has a better linearity compared with SSIM. Meantime in badly-blur images, SSIM assessment value has little change with the difference of blur, while RSSIM is still maintained a good assessment.

Conclusion

In this paper, a method of image quality assessment based on Region-Of-Interest and Structural Similarity is proposed. The experimental results show that the method has better linearity than the pure SSIM assessment method. At the same time in the badly-blur image and the local blur but whole acceptable image, RSSIM assessment method shows its advantage. However, this paper simply selects the full image weighted coefficient with 0.4, the image of interest area with 0.6 in the weight sum of Structural Similarity based on interest region and the overall similarity value, which is to highlight the importance of the full quality of the image. How to choose the weight to better in line with human subjective vision and linear needs further study.

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