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An Algorithm of Image Quality Assessment Based on Data Fitting of Image Histogram

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Abstract

Based on research the connection between the gray image histogram and the gray image quality assessment,an algorithm of the gray image quality assessment based on data fitting of image histogram is proposed.The improved algorithm also applies to the color image.During the course of the color image quality assessment,the histogram is fitted respectively based on the color components and the color quantization.The difference weight data of the fitting coefficients about the image to be evaluted and the reference image is calculated. And the two element evaluation is given according to in the given threshhold range. The experiments show that the image quality assessment is good when the difference weight data of the fitting coefficients about the image to be evaluted and the reference image Less than or equal to 5×10^{-5}*.The two element evaluation is also effectively given according to the fitting data about color histogram of the color image based on the color components and the color quantization.*

Key words: *Color Histogram, Data fitting, Color Image, Image Quality Assessment*

1. Introduction

It is important to set up the image quality assessment system in the field of digital image processing. Image quality assessment methods are divided into subjective image quality assessment method and the objective image quality evaluation method [1].

The subjective method is that the image quality is evaluated subjectively by the experimenter according to the designed experiment rules. ITU-T has issued standard of BT-510 to do the detailed provisions of test images, personnel, observation distance and the experimental environment in the process of the subjective quality evaluation [2-4].

The objective image quality evaluation method is to use a specific mathematical model to evaluate the image quality. According to the degree of dependence on the reference image [5-7], it has three kinds of methods on full reference, on falling quality reference and on no reference. The full reference image quality assessment method has formed the completely theoretical system and the mature evaluation framework [8-10]. It is computed the error between the reference image and the assessment image. The common error models are mean square error, root mean square error, mean square signal-to-noise ratio, SNR and PSNR etc.The image quality evaluation results between the subjective evaluation method and the objective evaluation method are often inconsistent. This shows that objective evaluation model based on the calculation error can not meet the needs of the image quality evaluation [11, 12].

In the objective evaluation system, the models of quality evaluation are based on statistical characteristics between the reference image and the assessment image.The histogram is the model of reflecting the image statistical features.When the results between the subjective quality evaluation method and the objective quality evaluation method are not consistent, the image histogram is one of the objective quality evaluation model. The algorithm based on histogram fitting is proposed.The method proposed in this paper is analyzed through a lot of experiments in the objective quality assessment of the gray image and the color image. The experiment results show that the method is effective.

2. Objective Image Quality Evaluation Criterions

The common error criterions are mean square error, root mean square error, mean square signal to noise ratio, SNR and PSNR etc [11].

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Let f(i,j) (i=1,2,…,N, j=1,2,…,M) be the reference image, g(i,j) (i=1,2,…,N, j=1,2,…,M) be the image to be evaluated.The formula for the mean square error can be written as:

$$E_{mse} = \frac{1}{NM}\sum_{i=1}^{N}\sum_{j=1}^{M}[f(i,j)-g(i,j)]^2$$

The formula for root mean square error can be written as:

$$E_{rms} = [E_{mse}]^{1/2}$$

The mean square signal to noise ratio can be written as:

$$MSNR = \frac{\sum_{i=1}^{N}\sum_{j=1}^{M}[f(i,j)]^2}{\sum_{i=1}^{N}\sum_{j=1}^{M}[f(i,j)-g(i,j)]^2}$$

Suppose $\bar{f}$ is $\frac{1}{NM}\sum_{i=1}^{N}\sum_{j=1}^{M} f(i,j)$, basic signal-to-noise ratio can be written as:

$$SNR = 10\lg\left[\frac{\sum_{i=1}^{N}\sum_{j=1}^{M}[f(i,j)-\bar{f}]^2}{\sum_{i=1}^{N}\sum_{j=1}^{M}[f(i,j)-g(i,j)]^2}\right]$$

Suppose $f_{\max}$ is the maximal pixel value, peak signal to noise ratio can be written as:

$$PSNR = 10\lg\left[\frac{NMf_{\max}^2}{\sum_{i=1}^{N}\sum_{j=1}^{M}[f(i,j)-g(i,j)]^2}\right]$$

The method of the subjective evaluation criterion is to select a group of experimenters to score the same image. The mean of the above scores is the subjective assessment of the image. Suppose that each score is Ci, the number of scoring each score is ni, the average subjective evaluation of MOS can be written as:

$$MOS = \frac{\sum_{i=1}^{k} n_i C_i}{\sum_{i=1}^{k} n_i}$$

In general, the MOS score is higher, the subjective evaluation of the image is better.

3. Image Quality Assessment Algorithm Based on Histogram Fitting

The core principle of the evaluation algorithm is to differently fit the histograms between the reference image and the image to be evaluated to the polynomials. The basic idea is that the histograms between the reference image and the image to be evaluated are fit to the polynomials with the same order. And the sum of the square of the difference of the two polynomial coefficients is calculated. The two element evaluation is given according to the above sum. The key of the algorithm is the method of determining the corresponding weighting coefficients of the polynomial coefficients.

The steps of the two element evaluation algorithm of the gray image quality based on the fitting histogram are as follows:

Step 1: Set the maximum difference of the pixel number with the same pixel value in the reference image and the image to be evaluated.

Step 2: Calculate the normalized histogram of the reference image and the image to be evaluated.

If the histogram function of the image is [8]:

$$H(s_k) = n_k \ (k = 0,1,2....L-1)$$

where the range of the gray value is [0,L-1] , the normalized histogram is represented as[1]:

$$p(s_k) = n_k / n(k = 0,1,2....L-1)$$

where p(sk) is the probability of the Kth gray value, sk is the corresponding gray value, nk is the corresponding pixel number, n is the total pixel number of the image.

In this paper, the histogram expressing the connection of the gray value and the number of pixels is fitted to the polynomial curve.

Step 3: Plot the histograms of the reference image and the image to be evaluated;

Step 4: Set the orders of fitting polynomial;

Step 5: Fit the histograms of the two images to be the polynomial curve. The calculation process is as follows:

At first the functionY=P(X) is created that P(X) is the closest data with the all data {(x,num)},x=0,1,2,…,L-1 in a certain criterion, where the row vector array is the ascending gray value x, and num is the row vector of the pixel number in the order of the ascending gray value , and NUM is the total number in the image. Y can be written as:

$$Y = c_0\varphi_0(X) + c_1\varphi_1(X) + c_2\varphi_2(X) + ... + c_m\varphi_m(X)$$

where c0,c1,c2,…,cm is the coefficients of the exponential function $\varphi_i(X)(i=1,2,...,m)$ in the ascending order. They make $\sum_{i=1}^{N}[P(X)-NUM]^2$ reach the minimum.

Step 6: Calculate the weight data of the coefficient difference sum of the two fitted polynomial. The calculation process is as follows:

Let A=B(X) be the fitting polynomial of the reference image histogram, Let C=D(X) be the fitting polynomial of the histogram image to be evaluated, then

$$A = B(X) = a_p X^p + a_{p-1} X^{p-1} + ... + a_1 X^1 + a_0$$

$$C = D(X) == c_p X^p + c_{p-1} X^{p-1} + ... + c_1 X^1 + c_0$$

$$E = \sum_{i=1}^{p+1} k_i (a_i - c_i)^2$$

Where the weighted coefficient kiin the range of [0, 1] is decreasing interval, and $\sum_{i=1}^{p+1} k_i = 1$.

Step 7: Output the quality evaluation of the image according to the calculation result E. If E≤TH, the image is good.Otherwise, the image is of low quality. In general, the threshold TH is given through a lot of experiments.

In this paper, the threshold TH for each pixel in step 6 is 5×10-5 through a lot of experiments.

4. Color Image Quality Assessment Algorithm Based on Histogram Fitting

4.1. Color Histogram

The image quality assessment algorithm based on histogram fitting is an effective method in Section 3. The improved method is applied to the objective evaluation of color image quality.The color image histograms are two forms of the color histogram and the component histogram.The color histogram is the statistical pixel number of all colors of image color based on a given color space. The color histogram can be applied to different color spaces [6, 7]. For example, the color histogram is defined as follows:

$$hist_{HSV}(h,s,v) = Np(H = h, S = s, V = v)$$

where H,S and Vare the numerical values representing three dimensions in HSV color space,N is the total pixel number, p(H=h,S=s,V=v) is the joint probability density function, and histHSV(h,s,v) is the pixel number with the color H=h,S=s,V=v.

The definition of the histogram normalization is defined as follows:

$$hist_{HSV}(h,s,v) = \frac{N(H = h, S = s, V = v)}{N} = p(H = h, S = s, V = v)$$

where N(H=h,S=s,V=v) is the pixel number with the color (h,s,v).

The method of color histogram is feasible in theory. But with the increase of the size of the image, the computation time of color histogram is long. The two forms of histogram in this paper are based on color quantization and based on color components.

4.2. Color Image Quality Assessment Algorithm Based on Color Component Histogram Fitting

The color component histograms are computed as follows. The pixel color values of the image are decomposed into three different components. So the three component histograms are got according to the method in Section 3.

The color image quality assessment algorithm based on color component histogram fitting is given as follows.

Step 1: Decompose the color image into the three different color components.

Step 2: Calculate the three component histograms of the reference image and the image to be evaluated.

Step 3: Set the order of the fitting polynomial, and fit the total histograms in Step 2.

Step 4: Calculate the three weighted data of every image through the method in Step 6, Section 3.

The three weighted data of the three components in every image are calculated. Suppose E1 is the weighted data of Component 1, E2 is the weighted data of Component 2, and E3 is the weighted data of Component 3, then

$$E_{sum} = \alpha_1 E_1 + \alpha_2 E_2 + \alpha_1 E_3$$

The three methods of $\alpha_1, \alpha_2, \alpha_3$ are given below.

The first case can be written as:

$$\alpha_1 = \alpha_2 = \alpha_3 = \frac{1}{3}$$

The second case can be written as:

$$\alpha_i = 1(i = 1,2,3), \quad \alpha_j = 0(j = 1,2,3, j \neq i)(E_i = \max(E_1, E_2, E_3))$$

The third case can be written as:

$$\alpha_1 = 0.6, \alpha_2 = 0.3, \alpha_3 = 0.1.$$

Step 5: Output the quality evaluation of the image according to the three calculation results Esum. If Esum≤TH, the image is excellent. Otherwise, the image is of low quality, here the threshold TH is given through a lot of experiments.

In this paper, the threshold TH for each pixel in step 6 is 5×10-5 through a lot of experiments.

4.3 Color Image Quality Assessment Algorithm Based on Color quantization Histogram Fitting

The color image quality assessment algorithm of histogram fitting based on color quantization is also a feasible algorithm [8]. The key step is how to quantilize the colors. In this paper the total colors are transformed to 256 kinds of representative colors. And the reference image and the image to be evaluated are differently quantized to the two color images only with two dimensions. Then the image quality assessment is given through the method in Section 3.

5. Experimental Results

5.1. Experimental Results of Gray Image

The experiments are performed on a Pentium 4 2.4GHZ PC running Windows XP, with 2.0GB memory and one 120 GB hard disk. The below results are got in MATLAB R2007a environment through editing M files and user defined functions.

The reference image in this section is a gray image with 256×256 pixels and 256 kinds of gray values. The images with different noisy intensity are compared with the reference image. The reference image is in Figure 1.

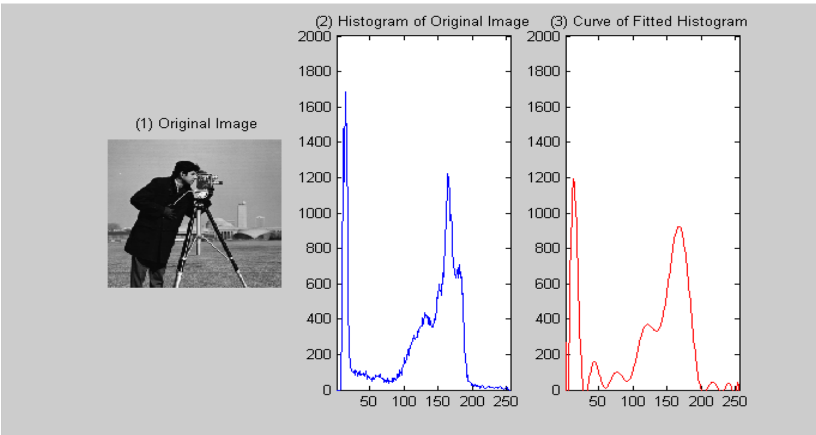

Figure 1. Histogram and curve of fitted histogram of original image

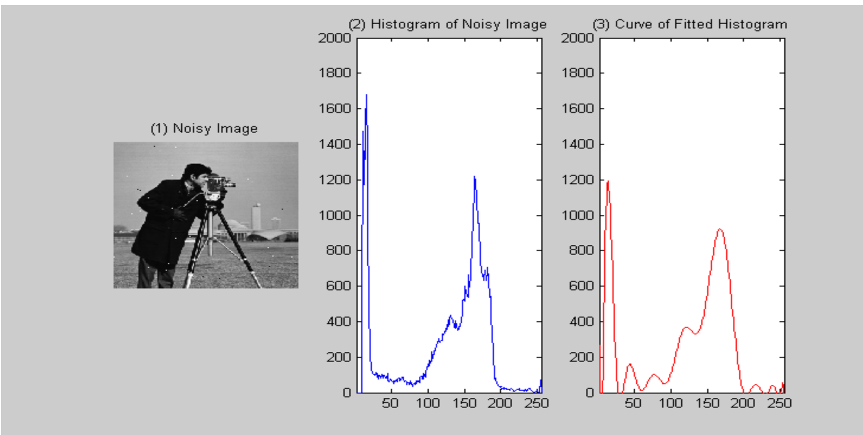

Figure 2. Histogram and curve of fitted histogram of noisy image (0.002)

The maximum order of polynomial fitting in this experiment is 20. It is evident that the method in Section 3 is effective to the geometric distorted images. The noise type is the kind of pepper and salt.The calculated histogram and the curve of the fitting histogram of the image with the intensity of 0.002 are shown in Figure 2. The calculated histogram and the curve of the fitting histogram of the image with the intensity of 0.02 are shown in Figure 3. The calculated histogram and the curve of the fitting histogram of the image with the intensity of 0.2 are shown in Figure 4. The data are shown in Table 1. The experiments also show that the method in Section 3 is effective to the noisy images. So the method in this paper can evaluate the gray image in reason.

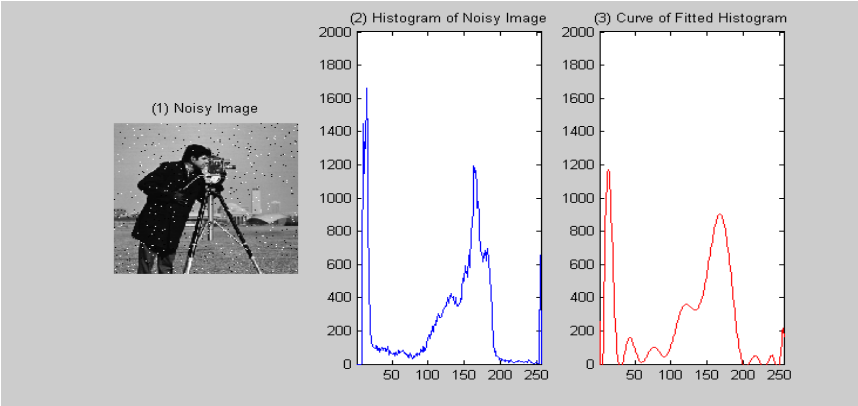

Figure 3. Histogram and curve of fitted histogram of noisy image (0.02)

Table 1. Data table of different noisy image

Noise Intensity	signal-to-noise ratio	the method in this paper	Quality of Image
.002	0.92893	4.5015e-004	good
0.02	1.0002	0.0161	bad
0.2	1.0007	1.4812	bad

5.2. Experimental Results of Color Image

The reference image in the experiments of Section 4 is the color image with 384×512 pixels and 2563 kinds of colors. The image in Figure 5 is the reference image. The image based on RGB color space is decomposed the three components. The results of the R component are in Figure 6. The results of the G component are in Figure 7.The results of the B component are in Figure 8. The maximum order of polynomial fitting in this experiment is 40.

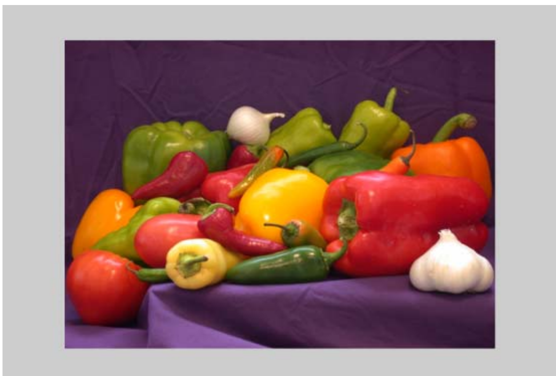

Figure 5. Reference color image

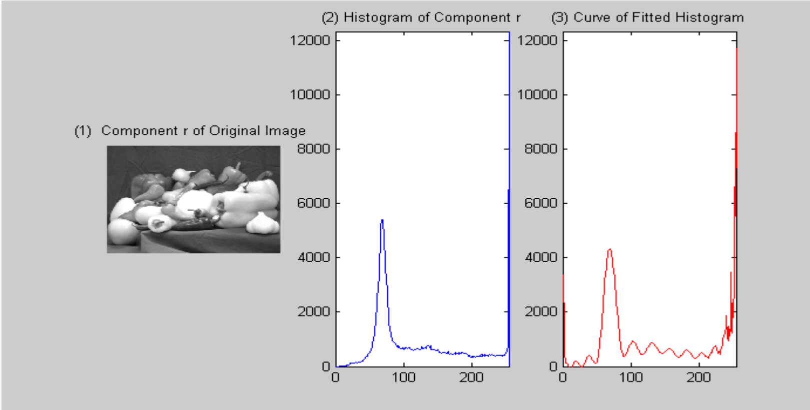

Figure 6. Histogram and curve of fitted histogram of the r component

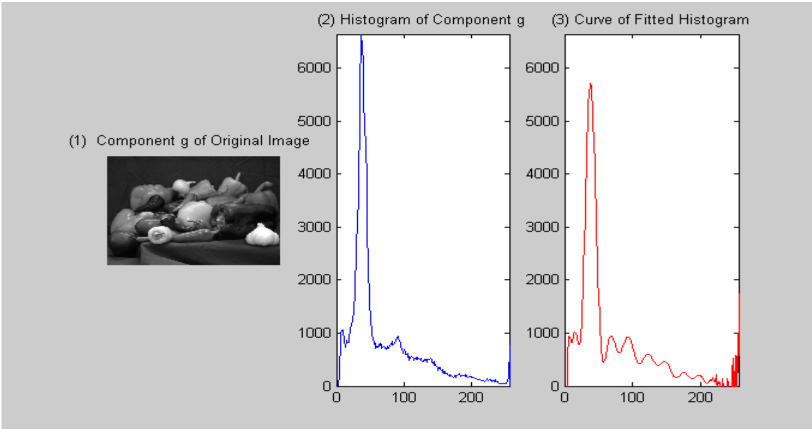

Figure 7. Histogram and curve of fitted histogram of the g component

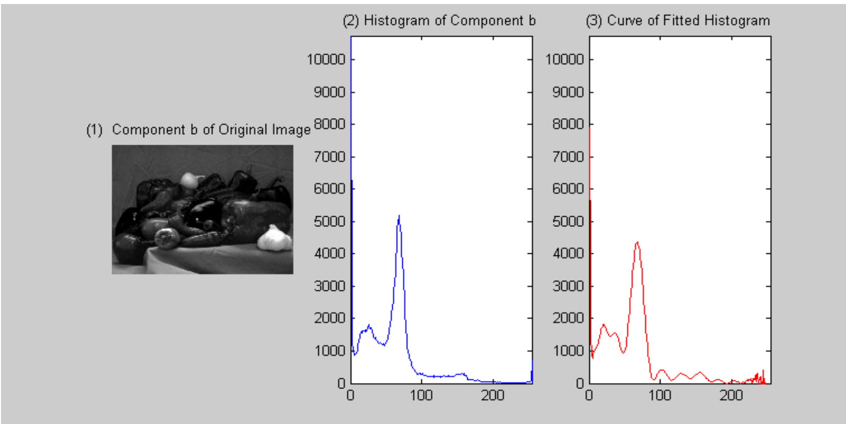

Figure 8. Histogram and curve of fitted histogram of the b component

The experiments also show that the method in Section 4 is effective to the noisy images. The noise type is the kind of pepper and salt. The noisy image with the intensity of 0.002 is shown in Figure 9. The results of the R component are in Figure 10. The results of the G component are in Figure 11. And the results of the B component are in Figure 12. The maximum order of polynomial fitting in this experiment is 40. The data are shown in Table 2.

Figure 9. Noisy color image

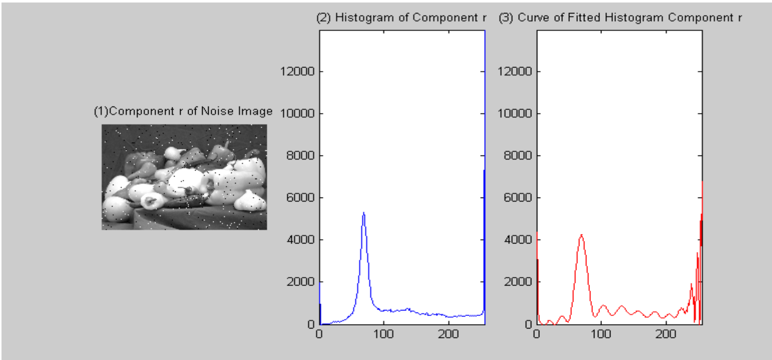

Figure 10. Histogram and curve of fitted histogram of the r component of noisy image (0.02)

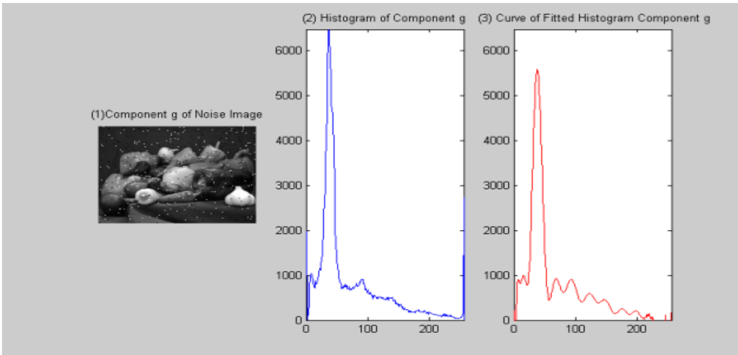

Figure 11. Histogram and curve of fitted histogram of the g component of noisy image (0.02)

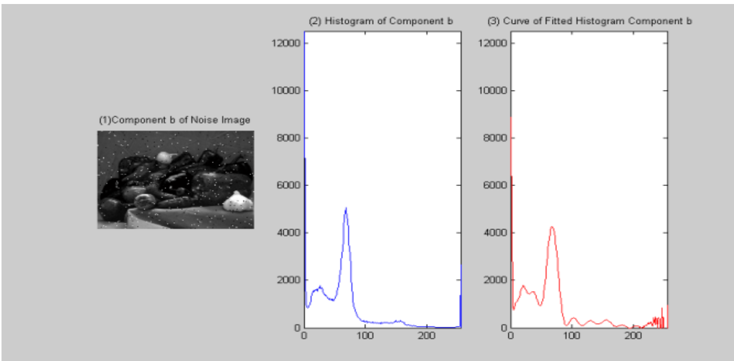

Figure 12. Histogram and curve of fitted histogram of the b component of noisy image (0.02)

Table 2. Data table of color image with different noise

Noise intensity	Component r	Component g	Component b	Quality of image
0.2	9.4205 e-005	0.0022203	0.00152879	bad
0.02	4.2116e-005	2.4737e-005	1.3713e-004	bad
0.002	1.2303e-005	1.2808e-005	1.7901e-00	good

From analyzing the data in Table 2, through the method in this paper the noise image is also evaluated in reason.

6. Conclusion

The method in this paper is not only suitable for the gray image, but also suitable for the color image. Through the calculation results between the noisy gray image and the reference image, the evaluation result is consistent with the image quality. The two forms of color histogram are the component histogram based on RGB color space and the color quantization histogram. The experiments show that the fitting computation based on the two forms can meet the need of evaluating the color image.

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