Chapter 33
A Method of Color Inverse Halftoning Image Quality Assessment Based on Image Structural Property

Zhixiong Shi, Xiaodong Wang and Lujing Fu

Abstract The traditional image quality assessment method and index cannot meet with the inverse halftoning image quality assessment. We proposed a color inverse halftoning image quality assessment method based on image structural property. First, we transformed printing image into inverse halftoning image with wavelet transforming inverse halftoning algorithm. Then, taking quaternion matrix as the carrier and combining with details of image, brightness and color information, we can convert halftoning image into quaternion matrix and obtain feature vector through singular value decomposition. Finally, the inverse halftoning image quality assessment is accomplished by calculating the quaternion singular feature vector angle to indicate the similarity of the original image and the inverse halftoning image. The result of experiment shows that the assessment can excellently exhibit the reduction of the inverse halftone image quality. Meanwhile, it is also in line with subjective visual perception and provides a reference for constructing quantitative assessment index of the inverse halftone color image quality.

Keywords Inverse halftoning · Image quality assessment · Quaternion · Wavelet transform

33.1 Introduction

Halftone is a process that we use the size or density of the dot to represent the image tone in printing. It can improve reproduction quality of continuous toning printing image. If second halftoning, image compression and enhancing process are done to the halftone image directly, it will result in a serious decline in image quality. So we

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need to restore the image into a continuous tone image [1], namely halftone image reversing. Halftone inversing refers to a process of reconstructing halftone image into continuous tone image, which is mainly to meet with the processing of printing image electronization, halftone image compression, sharpening, and secondary halftone. At present, the primary methods of halftone inversing include lookup table method [2], median pyramid transforming [3], wavelet transform [4], adaptive filtering [5], super-resolution analysis [6], etc.

Evaluating the quality of inversing halftone image can provide the most basic quantitative criteria for the performance evaluation of inverse halftone algorithm and further optimize the algorithm and its related parameters settings. Yang [7] conversed the color space to S-CIE Lab space to construct quantitative indicators of evaluating the quality of the color halftone inversing images, by defining the human visual perception of color difference images and gradient images. Jiang [8] uses image structural information to describe the mass reduction degree of color halftone inversing images, realizing color halftone inversing image quality evaluation based on image quality assessment method of structural similarity. Paper [9] set up halftone inversing color quality evaluation scheme using CIE DE2000 color difference formula and NBS color perception reference on the basis of HVS characteristics. But the proposed halftone inversing image quality assessment methods at present cannot fully reflect the distortion phenomenon of the halftone inversing image, and the correlation between the evaluation results and image subjective visual effect is small.

This paper proposes a quality evaluation method of color halftone inversing image, transforming image into a quaternion matrix form. The decline in brightness, color, and HVS sensitive structure information of the color image can be all included in the quaternion matrix, which can keep the direct image evaluation structure more in line with the human visual characteristics.

33.2 Inverse Halftone Image Quality Evaluation Technology

33.2.1 Structure Similarity Inverse Halftone Image Quality Evaluation Method

Structure similarity inverse halftone image quality evaluation method is founded on structural similarity of image quality evaluation. The differences between inverse halftone image and original image are measured by image structure information in the three aspects of brightness, contrast, and structure. Finally, the evaluation is completed. The inverse halftoning evaluation process [8] is shown in Fig. 33.1.

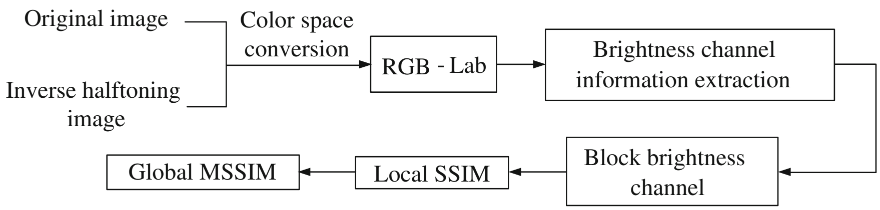

Fig. 33.1 Diagram for structure similarity inverse halftone image quality assessment

33.2.2 *Quaternion Inverse Halftone Image Quality Evaluation Method*

According to the basic theory of quaternion [10], assuming the quaternion real component is zero, the remaining three imaginary part can represent red, green, and blue components of color image, respectively, the color image can be represented as:

$$f(x,y) = r(x,y)i + g(x,y)j + b(x,y)k \tag{33.1}$$

$r(x, y)$, $g(x, y)$, $b(x, y)$ signify image on (x, y) color values of red green and blue. As a result, color images can be indicated by a quaternion matrix.

At the same time, quaternion matrix has singular value decomposition [11]. The color image is represented as a quaternion matrix form and obtained singular value vector through the quaternion matrix singular value decomposition. Then according to the degree of linear correlation between the two image singular value vector quaternion, we can acquire inverse halftone image quality evaluation method.

$s_{1,}$ s_2 represent original image and inverse halftoning image $I_{1,}$ I_2 quaternion matrix singular value vector, $s_1 = \text{diag}(\lambda_1, \lambda_2, \ldots, \lambda_r)$, $s_2 = \text{diag}\left(\lambda_1', \lambda_2', \ldots, \lambda_r'\right)$, QSVD evaluation index [12] can be represented as:

$$\text{QSVD} = \arccos \frac{\sum_{i=1}^{r} (s_1 \times s_2)}{\sqrt{\sum_{i=1}^{r} (s_1 \times s_1)}\sqrt{\sum_{i=1}^{r} (s_2 \times s_2)}} \tag{33.2}$$

$r = \min(\text{rank}(I_{1Q}), \text{rank}(I_{2Q}))$ QSVD scope for $[0, \pi/2]$ QSVD is smaller, the degree of linear correlation for image singular value vector is higher, the similarity between images is better.

The biggest advantage of using QSVD to evaluate the color inverse halftone image quality is that color inverse halftone images can be expressed with quaternion matrix and realized the parallel processing of color image color information, meanwhile the color image need not have to be decomposed into monochromatic color channel to process, which ensures the integrity of the color image processing.

33.3 Structural Characteristics of the Color Inverse Halftone Image Quality Evaluation

The method of color inverse halftoning image quality evaluation based on structure characteristics algorithm flow chart is shown in Fig. 33.2.

33.3.1 *Wavelet Transform Inverse Halftone Algorithm*

In inverse halftone image processing, we selects wavelet inverse halftoning algorithm for printing image processing [12], the algorithm process is shown in Fig. 33.3.

33.3.2 *Quaternion Inverse Halftone Image Quality Evaluation*

According to the inverse halftone image, using quaternion singular value decomposition of color inverse halftone image quality evaluation method for inverse halftone image quality evaluation, the algorithm flow chart shown in Fig. 33.4.

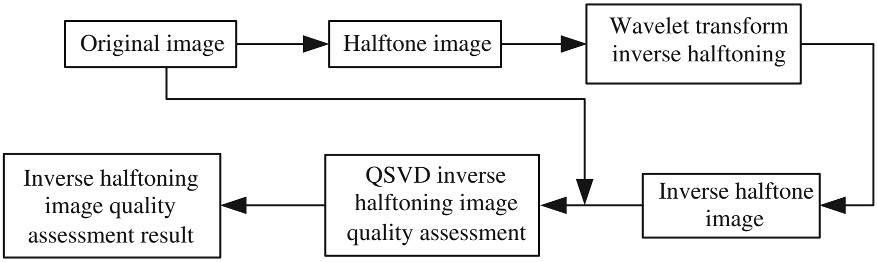

Fig. 33.2 Diagram for structural characteristics of the color inverse halftone image quality evaluation

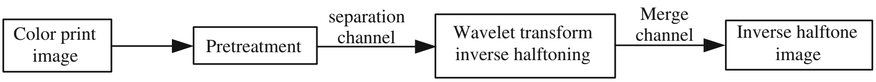

Fig. 33.3 Diagram for wavelet transform inverse halftone

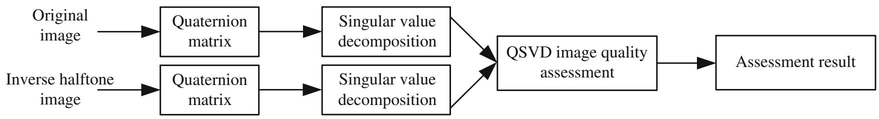

Fig. 33.4 Diagram for quaternion inverse halftone image quality evaluation

33.4 Experimental Results and Analysis

The experiment chooses TID2008 image database as the experimental images, and selects the wavelet transform algorithm for inverse halftone image processing, where the wavelet decomposition scale for two layers and the B spline wavelet as wavelet function. Meanwhile the experiment select structure similarity inverse halftone image quality evaluation method as a contrast experiments, image quality evaluation conduct to inverse halftoning for different screening modes and different dot form, respectively, the evaluation results are shown in Table 33.1.

By comparing the inverse halftone image quality evaluation results, we can see that the consistency and stability for QSVD is obviously better than SSIM for inverse halftone image quality assessment. Because compared to the original image, the image loss for inverse halftoning mainly concentrates on the image detail and the high-frequency part, and SSIM is not sensitive to the detail loss of the image, which leads to the evaluation results that inverse halftone images disagree with people's subjective feeling. At the same time, the human eye is more sensitive to the high-frequency part of image, and the quaternion matrix singular value can well describe the detail loss of the image, which can highlight the HVS sensitive information structure and improve precision of inverse halftone image quality evaluation.

Table 33.1 Inverse halftone image quality evaluation results

Screening mode	SSIM	QSVD	Screening mode	SSIM	QSVD
AM screening	0.8826	0.0455	FM screening	0.9515	0.0245
	0.7995	0.0152		0.9685	0.0132
	0.5208	0.0158		0.5108	0.0089
	0.7393	0.0234		0.7526	0.0253
	0.8616	0.0359		0.9344	0.017
	0.4271	0.0243		0.4081	0.0079
	0.9233	0.0119		0.902	0.0131
	0.4193	0.0308		0.3691	0.0204
	0.8688	0.0247		0.8674	0.0183
	0.3509	0.0476		0.3204	0.0155

33.5 Conclusions

This paper proposes color inverse halftone image quality evaluation method based on image structure characteristics, we convert color inverse halftone images into quaternion matrix and use quaternion singular value vector correlation of color inverse halftone image quality evaluation; then it improves the accuracy and stability for color inverse halftone image quality evaluation. The next step, we should conduct further research to the quaternion color image model, such as the image luminance variance as quaternion real component, highlighting the HVS sensitive image structure information of color image.

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