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Color Distortion of Digital Image and its Detection

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Abstract

To solve the problem of color distortion in the communication and reproduction process, the paper firstly analyzes the causes of the color distortion phenomenon. Then, the paper proposes the corresponding image color distortion detection algorithm based on the HSI color model. In the proposed method, the color image is transformed from RGB space to HSI space firstly; in HSI space, the reference image and the distortion image's hue differences and saturation differences are calculated. Experimental results on LIVE images show that the measured results of the model with subjective scoring after the nonlinear fit the correlation coefficient up to 0.95.

Keywords*: image quality assessment, HSI color space, color distortion, full-reference metric*

1. Introduction

With the development of computer applications and network communications, the way people communicate is no longer limited to telephone, e-mail and so on, but a more diversified exchange. Because of the color images with richer content than text, sound and image, and stronger performance, therefore, getting more and more favourable. It is the inevitable trend of communication. The widespread use of the color image is due to its accuracy in conveying information and better visual effect.

The problem of the color distortion of the color image gets increasing concerns in copy reproduction and communication process [4, 5]. This is not just becausethe hope to reproduce color images can show the true vibrant colors of the original, but more importantly, color image carries more and more information, this information includes true and accurate digital color signal (data) to pass and show. Therefore, how to evaluate the pros and cons of the quality of the video image can influence and improve the video image acquisition, processing and transmission of the ways and means to meet the requirements of the people on the video image quality, many experts and scholars have been exploring and researching on this subject.

For the color distortion of video image, it mainly has two types: subjective evaluation and objective evaluation. Subjective evaluation needs certain personnel according to certain rules to evaluate, this evaluation method needs high observation ability of the people, therefore need to develop a kind of objective evaluation method. Objective evaluation methods establish objective mathematical evaluation model in order to achieve the consistency with the subjective evaluation. In the objective evaluation, according to the algorithm to the dependence of source signals, color gamut evaluation can be divided into Full Reference evaluation system (Full - Reference, FR), and Reduced-Reference evaluation system (Reduced - Reference, RR) and No Reference evaluation system (No-Reference, NR) [1, 2, 3, 8, 9, 10].

The most simple full reference model is MSE, PSNR and so on. In recent years, the SSIM, VSNR, FSIM are gradually recognized by researchers. Among them, SSIM (structural similarity, SSIM) is a high quality evaluation criteria based on the kind of image structure information. From the angle of the image composition, it defines the structural information as independent of the brightness, contrast, reflect the attributes of the objects' structure in the scene, and distortion is modeled as a combination of brightness, contrast, and structure of the three different factors.

Since the SSIM algorithm is simple, accurate, after the presentation by the widespread concern of scholars at home and abroad, has been applied to a number of related areas.

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This article is based on the HSI color model, proposes the full reference image gamut distortion detection algorithm. In the HSI space, calculate the reference image and distorted image differences of hue and saturation differences. LIVE library related experiments show the effectiveness of the proposed algorithm.

The paper is organized as follows: Section I is the introduction (Introduction), Section 2 analyzes the causes of color distortion. Based on Section 3 HSI color model, Section 4 proposes the color distortion detection algorithm and the related experiments. And lastly, Section 5 draws conclusions.

2. Color Distortion Analysis

In the digital video image acquisition, processing (such as video image compression), the transmission and recording of the process, due to the imperfect imaging system, the processing method, the transmission medium and recording apparatus, combined with the movement of objects, defocus reasons, inevitably brought some image color distortions.

In the aspects of the video image coding, first, by motion to compensate the remove temporal redundancy, then an image is divided into a 8*8 pixel lattice, using the DCT (Discrete Cosine Transform) to remove spatial redundancy within each lattice, after the DCT completed to quantify and restructuring, the entire compression process greatly reduces the bit rate. However, the bit rate reduction is inevitably a loss of some of the original video information, the larger the compression is, the larger the color gamut differences between the coded image and the original image.

In the process of the image scanning process, the image is needed to split into discrete pixels, then collect each pixel's R, G, B information on the manuscript [6, 7, 11] point by point and row by row. During the scanning process, loss of the pixel color information will be caused Based on the acquisition of the image information in the image processing, all colors are carried out, and the color information of the image can not be increased. Therefore, for photo originals, scanning is a very critical aspect of the image processing, slightly improper operation will cause the color distortion of the video image.

In the channel transmission link, on the one hand due to the instability of the channel, packet loss or error may occur, so that make the image after transmission occurs the different degree of color distortion, these problems will directly affect the quality of the color gamut of the distorted image. On the other hand, the color gamut of the image quality will be decreased, with increasing transmission distance, and when the amount of image data exceeds a certain value, network congestion situation will be more serious.

3. HSI Color Space Model

HSI color space is a departure from the human visual system, which uses the Hue (Hue), color Saturation (Saturation), and Intensity (Intensity) to describe the color. HSI is to describe the color of a point inside the cylinder, the central axis of the cylindrical value since the black at the bottom to the top is white and among them is gray, angle around the axis corresponds to "hue", to this axis's distance corresponds to the "saturation", and the distance along this axis corresponds to the "brightness". As shown in Figure 1, the alpha angle is the color H, a value of 0°~360°, 0° is red, 120° is green, 240° is blue, point on the disc to the center's distance represents the saturation S, its value is 0 ~ 1, the center of the circle is 0.5, when I = 1 indicates the brightest is white, when I = 0 indicates the darkest is black [12-17].

This color space has two features, the first one is independent of the luminance component and the image color information; The second, Hue and saturation components is closely connected with the way people feel. This design approach reflects the way people observe the color. At the same time, it is conducive to the image processing.

This paper takes the color information based on HSI model, doed color distortion detection to the image. There are three reasons to select the model: (1) People's perception of colors through the light stimulation, color feeling, color perception, eventually formed three understandings of the object color: the category of the color, the purity of the color, the brightness of the color, while according to the above description, the three components of the HSI color model exactly corresponding with people's understanding of color, meet the people's visual habits and visual psychology, which is conducive to the use of computer knowledge; (2)

In the HSI color model, make the color feeling from human visual transformate into a particular numerical representation, so the program can easily use the color information, while in the RGB model, although use numerical represent color, but the program cannot base on human visual judgment mechanism effectively using the information contained in it, and the relationship among the three primary colors is big. (3) HSI color model separates the color information and the brightness information, H and S component represent color, I component represents light intensity, this point is particularly useful for the situation that process the various parts of the image luminance variation is large. The HSI color model enables us to use the difference of image color to get the purposes of detecting color distortion.

4. The Graphics Color Distortion Detection based on the HSI Model

4.1. The Image is Converted to the RGB Color Model

RGB color mode type, obtains a variety of colors through the change of the three color channels red (R), green (G), blue (B) and the superposition among them, RGB represents the red, green, and blue channels. The paper uses Equation (1), (2) and (3) to calculate the average value from the red, green and blue channels.

$$R = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N} r_{ij} \tag{1}$$

$$G = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N} g_{ij} \tag{2}$$

$$B = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N} b_{ij} \tag{3}$$

The R, G and B respectively represent the average values of red, green and blue; M and N respectively represent the height and width of the frame of the digital image; r_{ij}, g_{ij}, b_{ij} respectively represents the three colors red, green and blue pixels band intensity.

4.2. The RGB Color Model is Converted into HSI Model

RGB color model based on the Cartesian coordinate system, each color appears in the red, green, and blue primaries spectral components, the model is very satisfactory to the hardware's implementation, and matches the fact that human eye is sensitive to red, green, and blue, but do not reflect the essential differences among the colors, can not be consistent with human's perception of color. In order to easily describe the color image conducting color description, so as to in line with human's feeling facts of color, this paper is based on the HSI color model. Using this model, it can in the color image from the color information carried by erasing the intensity component's impact, so that make the description of the light intensity of the image's brightness information independent with the description of the hue and saturation of the image's color information.

For a given color image which stored as RGB format, after converting it to HSI model space, while the color distortion detection only use the hue and saturation, and its image's H and S components can be calculated by the following methods (4), (5) and (6).

$$\theta = \cos^{-1}\left\{\frac{0.5[(R-G)+(R-B)]}{[(R-G)^2+(R-B)(G-B)]^{1/2}}\right\} \tag{4}$$

$$\text{Hue}=\begin{cases}\theta & \text{if } B \le G\\ 360-\theta & \text{otherwise}\end{cases} \tag{5}$$

$$\text{Saturation}=1-\frac{3[\min(R,G,B)]}{(R+G+B)} \tag{6}$$

According to the formula (1), (2) and (3) R, G, B values was normalized to the range $[0,1]$, the color Hue is normalized to the range $[0,2\pi]$ using the value which gets from Equation (5) and divide it by 360, while the components of the Saturation itself has been in the range of $[0,1]$, which no longer need to be normalized .

4.3. Image Color Distortion Detection

In order to measure the color distortion of the image, we calculated the reference image and the distorted image's average hue and saturation values [18, 19, 20, 21]. Figure 1 shows that the reference image and the distorted image represents the hue and saturation in HSI color model.

Here θ_1 and θ_2 respectively represents the reference image and the distortion image's hue; Here a and b respectively represent the reference image and the transmission image's Saturation. $|\theta_1 - \theta_2|$ represents the angle difference of the image of the reference image and the distortion image. In the full-reference, it can use the hue and saturation's difference of the reference image and the distorted image to approximately calculate the distortion of the image in the color gamut.

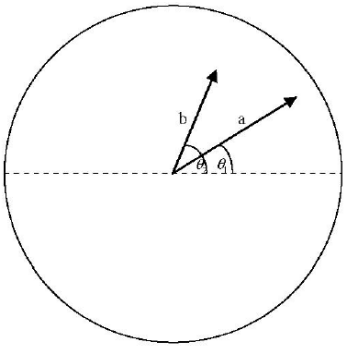

Figure 1. The HSI Color Model

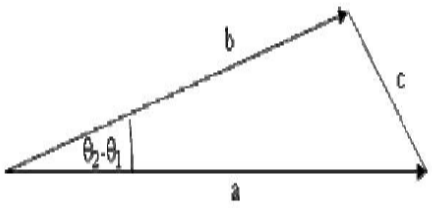

Figure 2. Relationship between the Reference Image and the Hue and Saturation of the Image Distortion

Image color can use reference images and distortion images hue and saturation common represent, Figure 3 shows the color distortion can use reference images and distortion images hue difference $|\theta_1 - \theta_2|$ and reference images and distortion images saturation represent. Here a represents the reference image's saturation matrix, b represents the distortion image's saturation matrix, using the size of C to indicate the degree of color gamut's distortion matrix, Formula (7) is the calculation formula for C.

$$C = \sqrt{a^2 + b^2 - 2 \cdot a \cdot b \cdot \cos|\theta_2 - \theta_1|} \quad (7)$$

$$c = \frac{1}{MN} \sum_{i=1}^{M} \sum_{j=1}^{N} C_{ij} \quad (8)$$

c is the image's final detection result of the color gamut, among them M and N respectively represent the height and width of the frame of the digital image.

4.4. Image Color Distortion Detection Results Analysis

Using formula (1)-(8), to detect the color distortion of the image, and analyze the results. In order to detec the model that the color distortion of digital image detection based on HSI color space, using these data to test the performance of the evaluation algorithm, LIVE Image Quality

Assessment Database generated in this case. The LIVE image library is a database which is provided by United States TEXAS University of image and video engineering laboratory, through a series of experiments obtain a subjective scoring of different degree of distortion. It contains five sub-library, 29 reference images and 982 estimated images, for jp2k (227 images), jpeg (223 images), whitenoise (174 images), gblur (174 images), fast_fading (174 images). In this paper, the images in wn sub-folder are chosen for experiments [14].

Table1. Reference Image A based on HSI Model Image Color Distortion Detection Results

	HUE(Hue)	Saturation (Saturation)	Distortion of the color gamut c
Reference image A	0.8926	0.093	
Distortion image 1	0.8949	0.0885	0.0931
Distortion image 2	0.8941	0.0909	0.0452
Distortion image 3	0.8885	0.0391	0.6935
Distortion image 4	0.8987	0.0776	0.2873
Distortion image 5	0.8969	0.0833	0.1956

Reference image A

Distorted image 1

Distorted image 2

Distorted image 3

Distorted image 4

Distorted image 5

Figure 3. Experimental Image

According to the reference image A based on HSI model image color distortion detection results, we can see, after transmitting image 3's image color distortion is largest, occurred a more serious image distortion during the transmission; after transmission image 2's image color distortion is smallest, can approximate believe that didn't happen image color distortion during transmission. Other images occurs different degree of image color distortion during the transmission.

In order to show the objectivity of the evaluation of the experimental results, conducting image color distortion detection to 145 images in the image library, based on the subjective evaluation value, fitting with the color distortion detection results, after fitting the nonlinear regression correlation coefficient is 0.95.

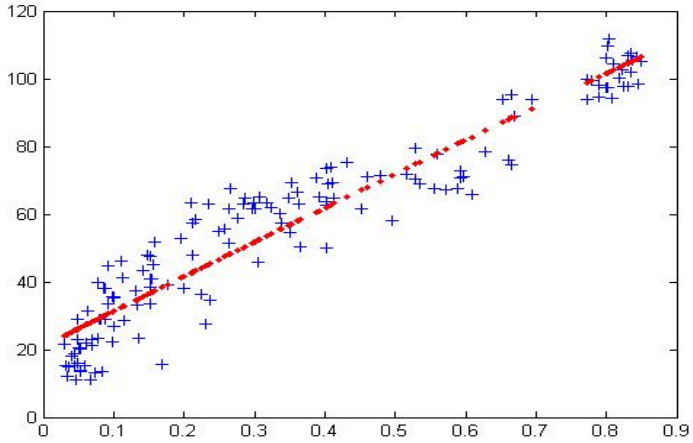

Figure 4. Proposed Algorithm Fitting with the Subjective Evaluation Value

From fitting effect, the algorithm's subjective and objective assessment have a good consistency, also reflects the effectiveness of the model.

5. Conclusion

With the rapid development of information technology, people put forward higher requirements on the quality of the image transmission. Further study of the image color distortion detection, improving the foundation of image color gamut matching technology, can improve the users feelings of using digital TV, mobile video, IPTV business, and improve the operation and maintenance quality of the operators, and has important practical significance and market value to promote the application and popularization of digital TV, mobile video, IPTV.

In this paper, the color distortion problem of image in the process of communication and replication reproduction, based on reference the existing work, in-depth analysis of the causes of the color distortion. Based on the HSI color model, the paper proposed the corresponding image color distortion detection algorithm. Firstly, the true color image converted from RGB space to HSI space, and then calculating a reference image and a distorted image's hue differences and saturation differences. LIVE library's related experiments show, the model test results and subjective scoring after nonlinear fitting has higher correlation coefficient, subjective and objective assessment have a good consistency.

Of course, due to the video image's final receiver is the person, so, study how to further meet the visual perception and visual interest to the image color distortion detection algorithm, and does not depend on the reference image's no-reference color distortion detection, will be the study direction and focus of the next phase.

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