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ITJ

ISSN 1812-5638

INFORMATION TECHNOLOGY JOURNAL

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 12 (20): 5783-5790, 2013
ISSN 1812-5638 / DOI: 10.3923/itj.2013.5783.5790

Color Calibration Based on the Removal of Isolated Distortion Pixels

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Abstract: Taking into account human visual characteristics, when isolated distortion pixels disperse sufficiently in an image, these pixels have minimal effect on the visual images. This study presents a color and brightness correction method based on lαβ color space transformation and excluding isolated pixels with brightness distortion. The experimental results show that the method can obtain better brightness and color uniformity in the vision, as well as make the histograms of corrected images in three channels get closer to normal distribution. Furthermore, the method suggested in this study can better reflect the transformation of surface features in the images.

Key words: Color calibration, color space transformation, isolated distortion pixels

INTRODUCTION

Currently, there have been lots of techniques and methods to obtain large area and high resolution images, such as mosaic of multi-temporal remote sensing images (Chen *et al*., 2009), formation of large scale projection wall using multi-projector (Wang *et al*., 2007a, b). Moreover, these techniques and methods have a common feature in real terms. Namely they divide the large area of high-resolution image into each sub-image to process, respectively and then all of the sub-images are displayed simultaneously into one in order to achieve a large area of high-resolution image. However, the brightness of sub-images is inconsistent frequently because the acquisition time of remote sensing images or processing device of sub-images is difference (such as different brightness of the projector, etc.). So, the brightness differences of sub-images lead to brightness or color defects of mosaic image. Aiming at these defects, a lot of research works have been done. For example, based on remote sensing automatically classification and lαβ color space transformation, Chen *et al*. (2009) proposed a color calibration method and overcame the deficiency that Overlapping Regions Linear Map (ORLM) can not represent data distribution of the full image. Wang *et al*. (2007b) presented a generalized color model for projectors color calibration and built a tiled display walls with high-precision visual seamlessness only by employing a digital camera.

Jackman *et al*. (2012) combined a linear colour space transform and advanced multiple regression methodologies to reduce the colour calibration error substantially. Jia *et al*. (2013) proposed an optimization color correction algorithm to correct the luminance and chrominance of the projector based on Pedro's image segment and a new weighting function with the mapping relationship between input and output of camera's pixel value and Zhu *et al*. (2012) proposed an adaptive calibration algorithm for projected images which enables ordinary projectors to project on arbitrary surfaces in daily environment. But these research works only consider the color space, or isolated pixels of brightness distortion in the images. Therefore, through lαβ color space transformation and excluding isolated pixels of brightness distortion, this study presents a color and brightness correction method to eliminate the brightness inconsistent of images.

MATERIALS AND METHODS

Taking into account human visual characteristics, when isolated distortion pixels disperses sufficiently in an image, these pixels effect on the visual images with minimal impact. If these isolated distortion pixels can be eliminated before brightness correction is executed, the gray levels range of image can be effectively extended. Thereby, the display quality of image can be improved. This is mainly due to isolated luminance pixel itself has little effect on human vision but its' distortion value results in a great impact for the calculation of statistical values. Therefore, the results of color and brightness correction methods based on statistical values will be interfered, especially when the image has some isolated distortion pixels with particularly high brightness values.

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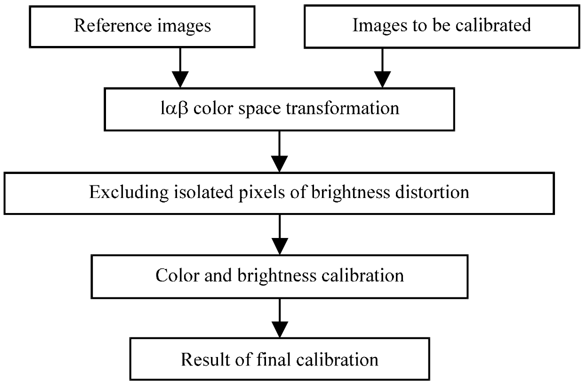

Fig. 1: Flow diagram of color calibration method

The flow diagram in Fig. 1 is illustrating the color calibration method based on lαβ color space transformation and excluding isolated pixels of brightness distortion.

lαβ color space transformation

lαβ color space put forward by Ruderman *et al.* (1998) is introduced in this study in order to get rid of the influence of the correlations between the channels from which images obtained and the three channels of RGB color space. The major characteristic of the color space is the minimal correlation influence of the channels in most natural scenes images. The color space provides three de-correlated, principal channels corresponding to an achromatic luminance channel l and two chromatic channels α and β which roughly correspond to yellow-blue and red-green opponent channels.

lαβ color space is a variety from cone color space LMS, so RGB color space images should be changed into LMS color space ones first. The transformation formula is as follows:

$$\begin{bmatrix} L \\ M \\ S \end{bmatrix} = \begin{bmatrix} 0.3811 & 0.5783 & 0.0402 \\ 0.1967 & 0.7244 & 0.0782 \\ 0.0241 & 0.1288 & 0.8444 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \tag{1}$$

After the transformation, there will be large skew in statistical distribution of the image data which can be eliminated by the transformation from LMS color space into logarithm LMS space. The transformation formulas are as follows:

$$\begin{aligned} L' &= \log L \\ M' &= \log M \\ S' &= \log S \end{aligned} \tag{2}$$

Then logarithm LMS space images can be changed into lαβ color space images through following equation:

$$\begin{bmatrix} l \\ \alpha \\ \beta \end{bmatrix} = \begin{bmatrix} \frac{1}{\sqrt{3}} & 0 & 0 \\ 0 & \frac{1}{\sqrt{6}} & 0 \\ 0 & 0 & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & -2 \\ 1 & -1 & 0 \end{bmatrix} \begin{bmatrix} L' \\ M' \\ S' \end{bmatrix} \tag{3}$$

Isolated degree of distortion pixel: The isolated degree of distortion pixel is based on two factors: the brightness difference between adjacent pixels and the overall dispersion in the whole image. Therefore, the degree of dispersion is defined as the isolated degree of distortion pixel, denoted I_E (x, y) (Wang *et al.*, 2007b):

$$I_E(x, y) = L(x, y) - \frac{1}{W \times H \times m} \times \sum_{i=1}^{m} [L_i \times D_i \times \sigma] \tag{4}$$

where, L(x,y) is the luminance value of distortion pixel; W and H is the image resolution; m is the number of all possible luminance value; L_i is the i-th possible luminance value; D_i is the number of L_i in the image; σ is the sample variance of the image.

Color and brightness calibration: By calculating the means and variances of the reference image and image to be calibrated after the lαβ color space transformation, respectively, the data distribution of the image to be calibrated can be matched on that of the reference image by applying linearity models (Hertzmann *et al.*, 2001). The equation is as follows:

$$Y(p)' = \frac{\sigma_2}{\sigma_1}(Y(p) - \mu_1) + \mu_2 \tag{5}$$

where, μ_2, σ_2, μ_1 and σ_1 are the means and variances of the reference image and image to be calibrated, respectively. Y(p) is the value of a pixel in the image to be calibrated after lαβ color space transformation and Y(p)' is the value of the pixel after the calibration.

RESULTS

Two images were experimented with the method suggested in this study and to look at the image on the visual clarity, all of the illustrated images were carried out enhancement display based on the standard deviation of image. The original images are presented in Fig. 2, in which (a) is the reference image and (b) is the image to be calibrated. Figure 2 and the means of different channels of original images in Table 1 indicate the existence of large differences in the color and the brightness of both the vegetation and the water between the reference image and the image to be calibrated.

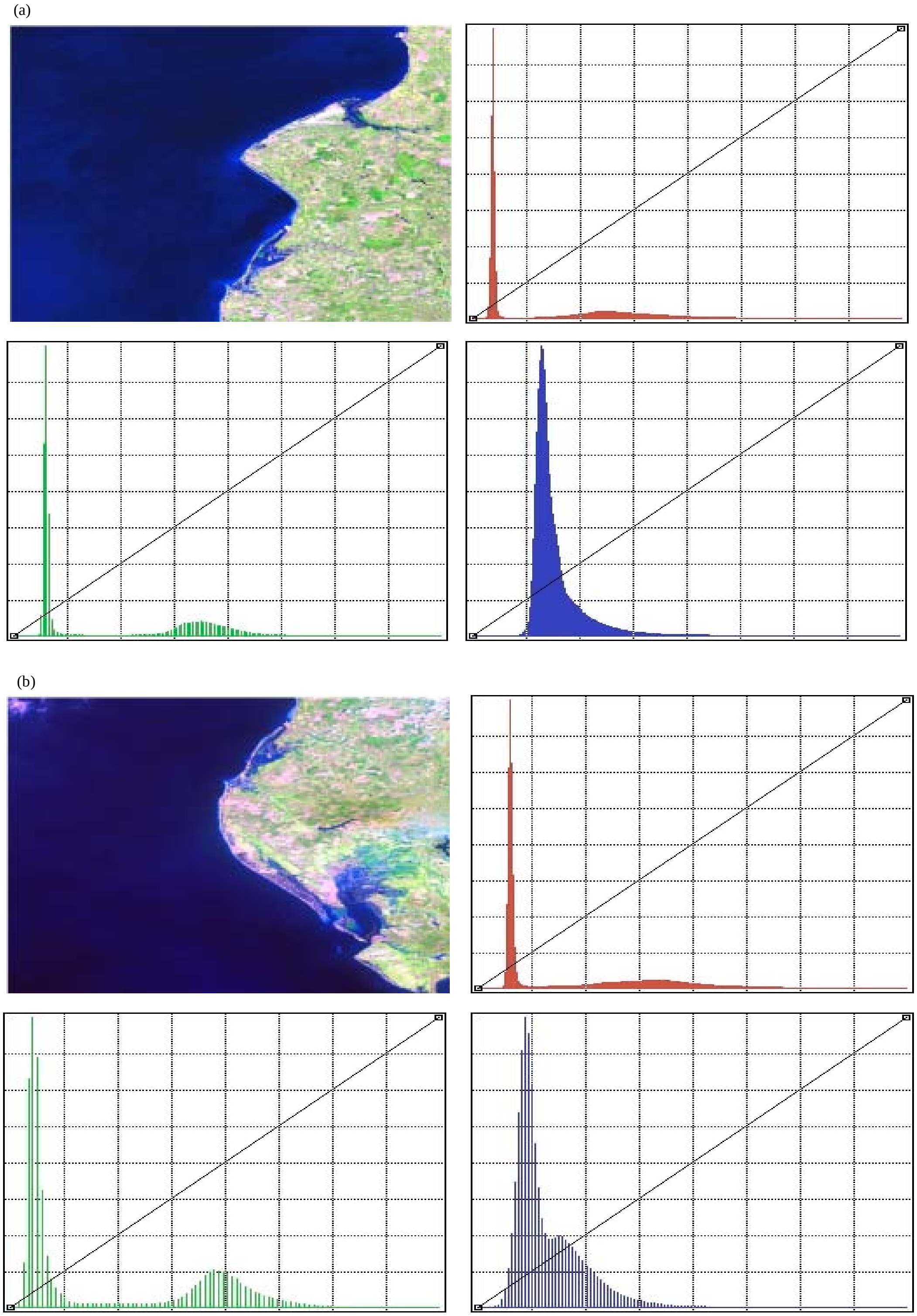

Fig. 2(a-b): Original images and their histograms (a) Reference image and its histograms and (b) Image to be calibrated and its histograms

Table 1: Statistics comparison of images before and after color calibration

Statistics variable	Channel	Reference image	Image to be calibrated	Image calibrated without RIDP	Image calibrated with RIDP	Mosaic image calibrated without RIDP	Mosaic image calibrated with RIDP
Mean	1	39.69	50.32	44.69	43.13	40.84	41.17
	2	32.82	43.32	37.84	37.07	34.46	35.52
	3	50.98	87.17	56.22	54.03	53.47	53.39
Variances	1	41.08	44.46	40.73	39.48	40.31	38.89
	2	28.45	20.16	28.28	28.48	28.14	28.05
	3	15.73	9.55	10.96	9.88	13.20	11.99

RIDP: Abbreviation for Removal of isolated distortion pixels

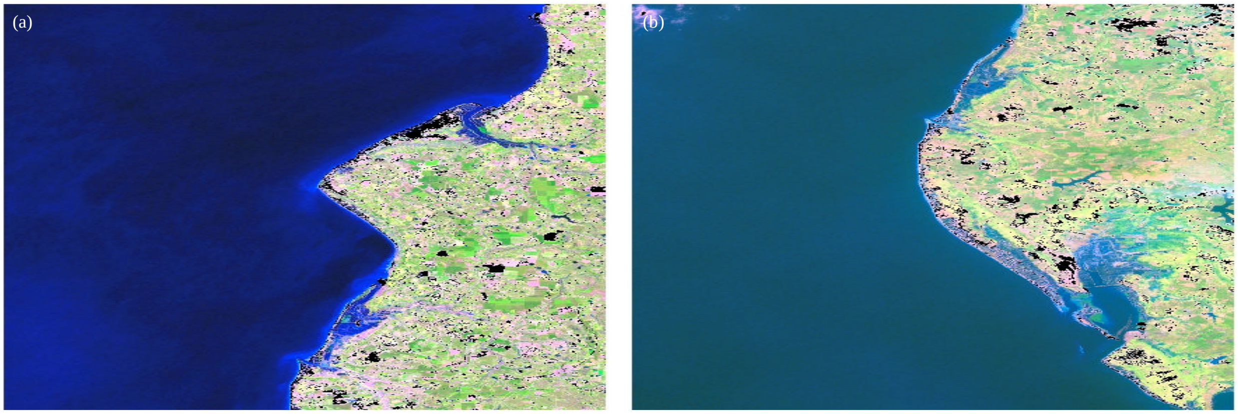

Fig. 3(a-b): Results of eliminated isolated pixels

Results of excluding isolated pixels of brightness distortion: Based on the definition of the isolated degree of distortion pixel, the results that one percent isolated pixels of brightness distortion in the image were excluded are displayed in Fig. 3. From the Figure we can see, the high brightness isolated pixels in original image have been well removed.

Results of calibration: As can be seen from the Fig. 4, the color and brightness difference between the images are corrected by both methods that isolated pixels were removed or not removed. But the method of excluding isolated pixels makes the histograms of three channels more similar to the reference image and closer to normal distribution. According to the statistics comparison of images before and after color calibration in Table 1, we can find both methods of removing and not removing isolated pixels have modified the image to be calibrated.

But as can be seen from the mean values, the method of excluding pixels with brightness isolation gets greater compression of the brightness of the original image in three channels which makes it closer to the reference image in brightness. Furthermore, the change of the variance values better reflects the transformation of surface features in the images when the method removing isolated pixels was used. The first and third channels, namely the red and blue channels mainly reflect the characteristics of bare land and water changes and the changes of color and brightness of them are not very significant in the whole image. Therefore, the method removing isolated brightness pixels gets smaller variances in these two channels and reflects the bare land and water bodies relatively more homogeneous. And the second channel, namely the green channel mainly reflects the changes of land vegetation in the image. Due to the colors of vegetation have significant changes from dark green to light yellow, the method suggested by this study gains greater variance change in this channel and better reflects the quite different changes of vegetation.

Results of mosaic: Figure 5a indicates the great differences in color and brightness in the original mosaic image and the differences still exist after color correction. But the mosaic results show that the mosaic images corrected with removing isolated pixels are better than that corrected without removing isolated pixels. The mosaic line between images is distinct in Fig. 5b while the line is not easy to see in Fig. 5c. Obviously, the method suggested in this study obtains a better brightness and color uniformity in the vision, as well as the histograms from three channels can get closer to normal distribution as can be seen from Fig. 5d-f.

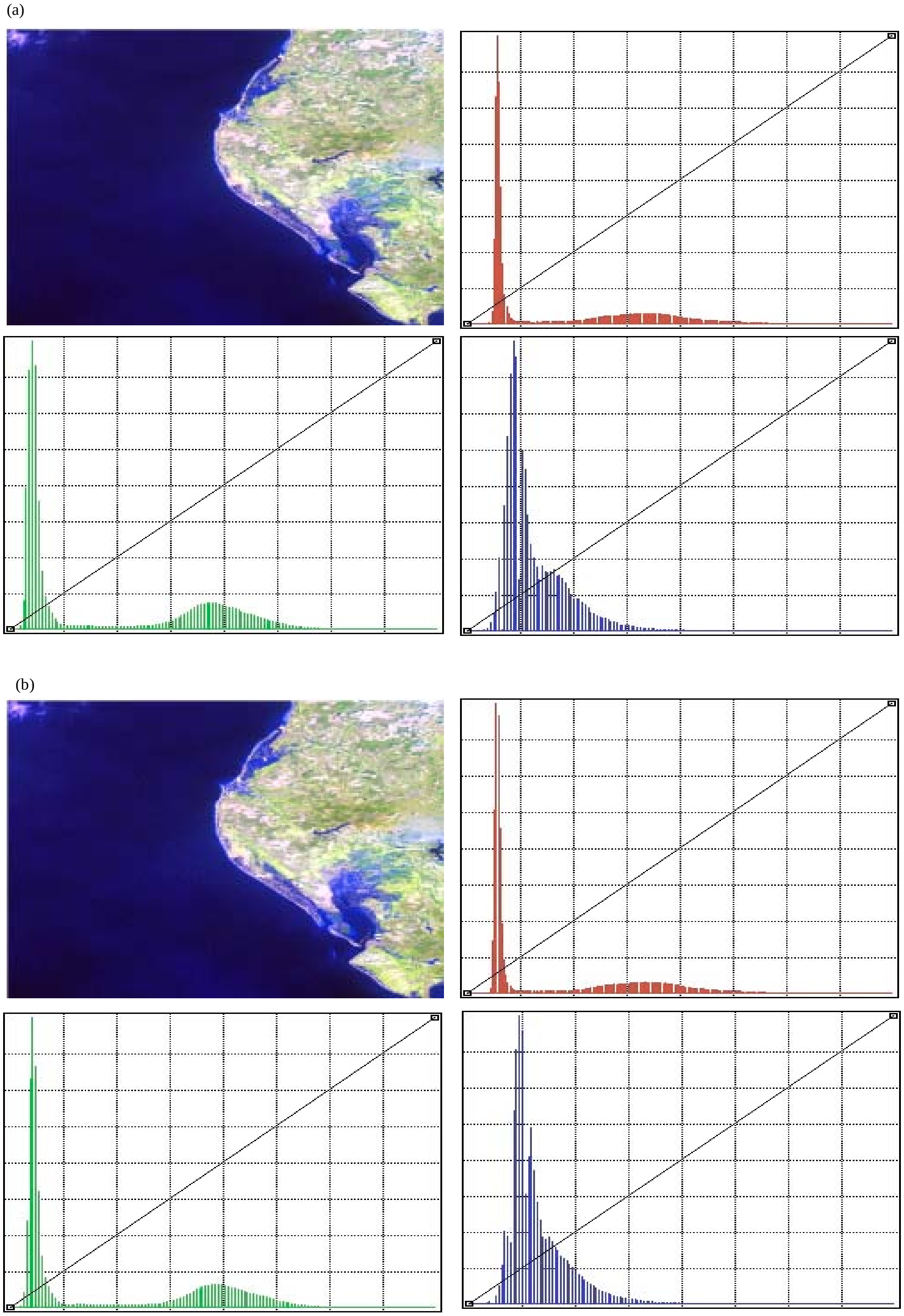

Fig. 4(a-b): Calibrated images and their histograms (a) Image calibrated without removing isolated pixels and its histograms and (b) Image calibrated with removing isolated pixels and its histograms

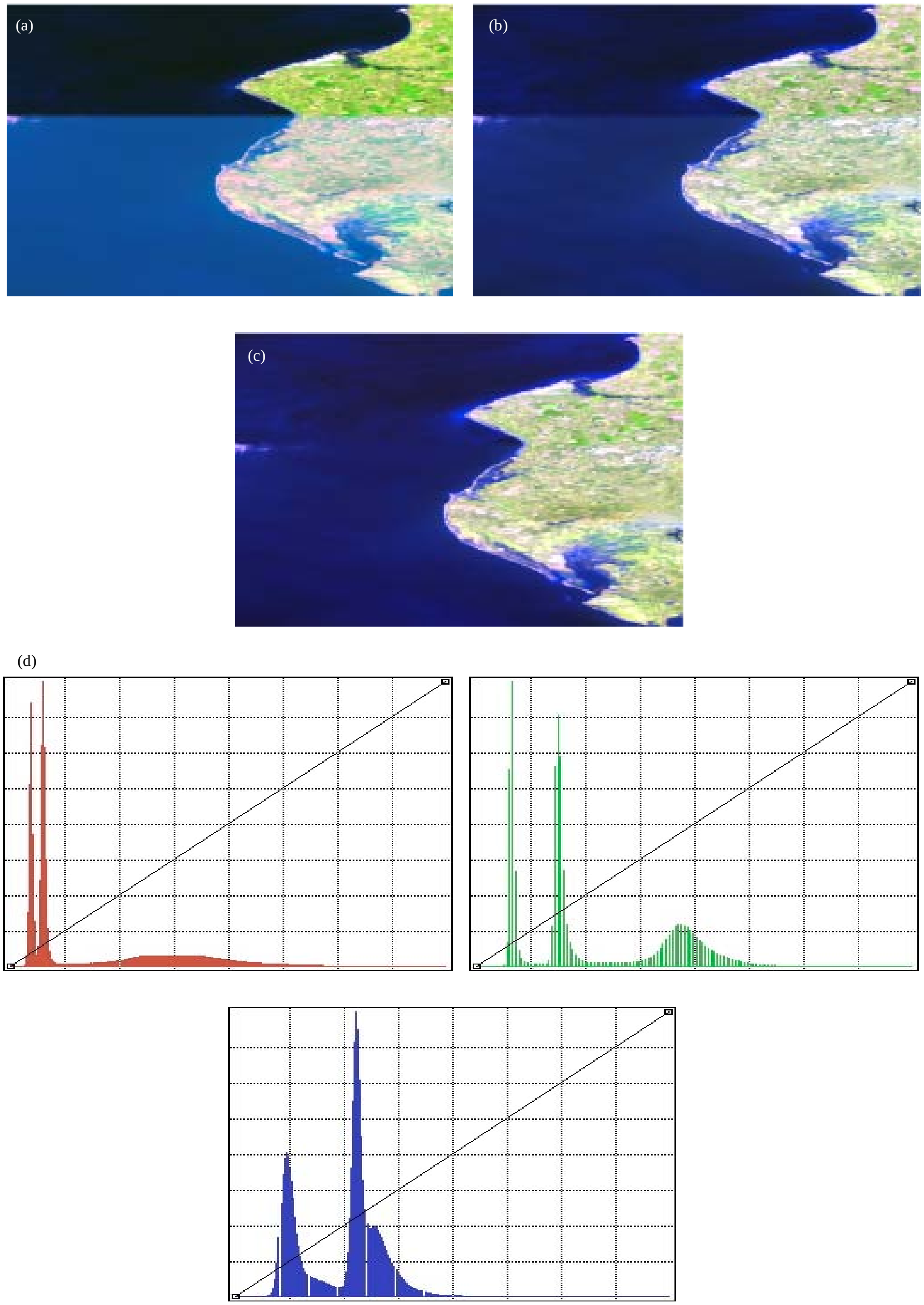

Fig. 5(a-f): Continue

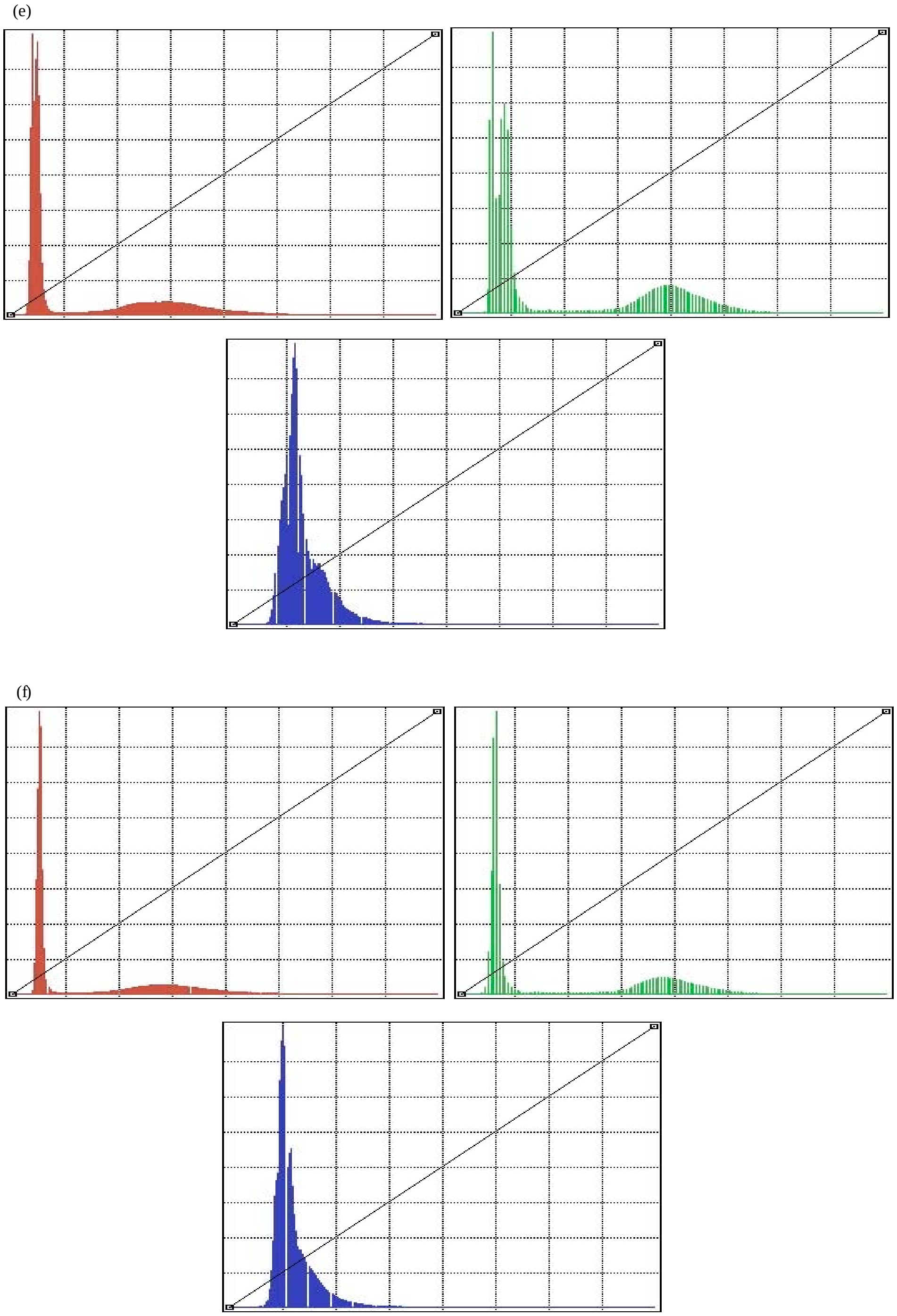

Fig. 5(a-f): Mosaic images and their histograms (a) Original mosaic image, (b) Mosaic image calibrated without the removal of isolated distortion pixels, (c) Mosaic image calibrated with the removal of isolated distortion pixels, (d) Histograms of original mosaic image, (e) Histograms of mosaic image calibrated without removing isolated pixels and (f) Histograms of mosaic image calibrated with removing isolated pixels

CONCLUSION

Taking into account human visual characteristics, when isolated distortion pixels disperse sufficiently in an image, these pixels have minimal effect on the visual images. If these isolated distortion pixels can be eliminated before brightness correction is executed, the gray levels range of image can be effectively extended. Thereby, the display quality of image can be improved. This study presents a color and brightness correction method to eliminate the brightness inconsistent of images based on lαβ color space transformation and excluding isolated pixels of brightness distortion and the experimental results show that the method can obtain a better brightness and color uniformity in the vision, as well as the histograms from three channels can get closer to normal distribution. Furthermore, the method suggested in this study can better reflect the transformation of surface features in the images.

ACKNOWLEDGMENT

This study is supported by National Nature Science Foundation under Grant (61262070) and applied basic research programs of Yunnan Province (2010CD047, 2011FZ140)

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