Multiple reference images based on lookup-table color image fusion algorithm

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Abstract

Natural feeling color image fusion technology is an important direction in image processing. This paper first summarizes contributions from both domestic and foreign researchers. Then according to the theory of 2D color-lookup-table, it puts forwards the multiple reference images fusion algorithm, and gives the results of using two and three reference images. The comparing and analyzing of those results proves the validity of the algorithm.

Keywords: color-lookup-table, multiple reference images, color fusion.

1. Introduction

With the development of multiband imaging sensors and digital image processing technology, the visible light (low light), near infrared imaging, short wave infrared / MWIR / LWIR imaging multiband fusion technology becomes one of the key directions of research at home and abroad. One of the main goals of multiband color image fusion algorithm is to pursuit natural feeling color of fusion images. In 2001, professor Erik Reinhard from University of Bristol first proposed color transfer in $l\alpha\beta$ space, then Welsh[1], Vieira[2], Gary R. Greenfield[3], Yu-Wing Tai[4] from HK, Yufeng Zheng and Edward A. Essock[5] made contributions in image fusion improving. In 2003, Alexander Toet[6-9] from TNO laboratory in Holland innovatively took color transfer into color night vision research field. This years, Lingxue Wang and Weiqi Jin from Beijing Institute of Technology(BIT) proposed color transfer based image fusion algorithm in YUV space [10,11], and realized low light/IR double-band natural feeling color night vision real-time hardware processing and applying in equipment.

In 2010, A. Toet put forward a natural color image fusion method based on 2D lookup-table [12,13], which made fusion images have comfortable natural color. Yuanmeng Zhao and Lingxue Wang[14] from BIT then proposed a new lookup-table based fast natural color video fusion algorithm.

The 2d color-lookup-table based color transfer algorithm has made positive progress, but it is still difficult to guarantee the stability of fusion image color. It is because different band of detectors has different gray scale in output images, color fusion images need to be adjusted in brightness and chroma parameters

according to scene environments. Meanwhile, the fusion images have great effect from reference image, thus reduces the natural feeling. This paper researches those questions and proposes a method in building 2D lookup-table from multiple reference images, realizing better visible light (low light) / infrared image natural color fusion processing.

2. 2D color-lookup-table building methods

2.1 TNO method

The way in building lookup-table of TNO method is shown as Fig.1. (1)Build a red-and-green lookup-table with the size of 256×256 in RGB space. (2)Transfer both of the red-and-green lookup-table and reference image into $l\alpha\beta$ space, then transfer the color of reference image to the red-and-green lookup-table to build a new lookup-table. (4)Return the new lookup-table to RGB space [13], the flow chart is shown as Fig.1.

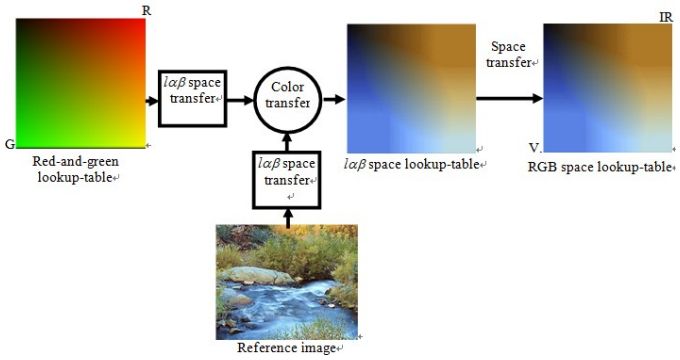


Fig.1 Flow chart of TNO method

TNO method has a fast speed of processing and easy to be realized, but it demands a high stander of reference images, because the hue of fusion images can be greatly influenced by reference images. Also, color in red-and-green lookup-table has little relationship with source image, which makes the algorithm difficult to suit every scene.

2.2 BIT method

In 2009, Yuanmeng Zhao and Lingxue Wang from BIT put forward a new method of building lookup-table[14]. Make the double-band image false color processing firstly, turn together with reference image into YUV space[10], and return to RGB space after color transfer. Scan the double-band gray images and color transfer image synchronously, take color values (R, G, B) of all of the same pixel positions from the two gray images and establish an incomplete color-lookup-table. For those pixels without color values, give them a mean value from nearest pixels in Euclidean distance, and become the complete color-lookup-table, flow chart is shown as Fig.2.

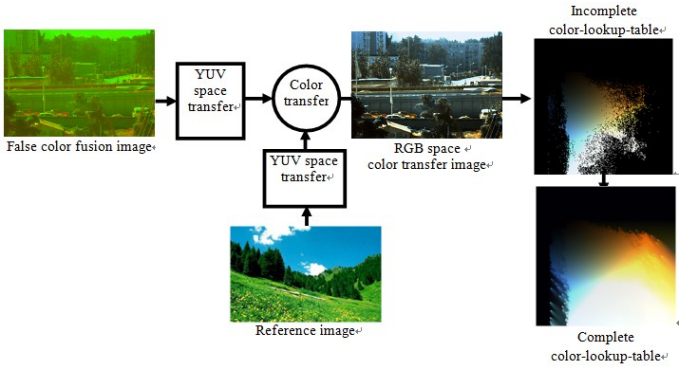


Fig.2 Flow chart of BIT method

The lookup-table in BIT method relates both to reference image and scores images. So the result of fusion can be predicted by judging different scenes and its reference images, thus getting a stable fusion color relatively. However, the hue of complete lookup-table changes with reference image obviously.

3. Multiple reference images based on lookup-table color image fusion algorithm

3.1 Establishment of 2D color-lookup-table

The thought of algorithm is based on the lacks the two methods, flow chart is shown as Fig.5. The specific steps are adopted as follows:

Step1: (False color fusion) Put the IR and visible light gray image into R and G channel respectively to get the false color fusion image.

Step2: (False color lookup-table) Establish a coordinate system according to the false color fusion image, and from which extract a false color lookup-table L_0.

Step3: (Complete lookup-table) Repair and establish a complete color-lookup-table L. Scan L_0 pixel-by-pixel, accumulate the color values on the nearest diamond path around each target point, take the average value and assign it to the corresponding point in complete lookup-table. Let A as distance between pixel and target point, as shown in Fig.3.

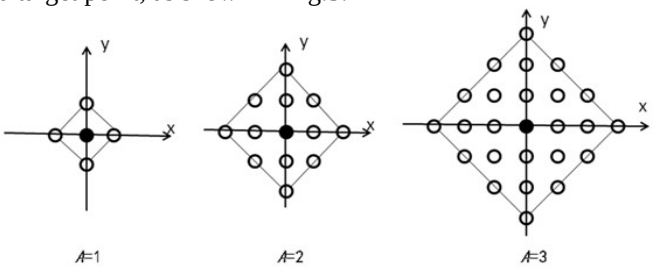


Fig.3 Pixel positions in different values of A

Step4: (Color transfer) Transfer the natural color of *l* pictures of reference images to the complete lookup-table respectively in $l\alpha\beta$ space to get *l* pictures of color lookup-tables (transfer relationship, see Ref.13).

Step5: (Linear combination) Linear combine the l,α,β components of every two lookup-tables with and get combined lookup-table $L_1^{'}$, $L_2^{'}$,..., $L_l^{'}$. The Linear combination is as follows:

$$L_l^{'} = k_1 \times L_m + k_2 \times L_n \tag{1}$$

Where， m, $n \in [1, l]$， k_1、$k_2 \in [0, 1]$。

Step6: (Space transfer) Return the lookup-tables $L_1^{'}$, $L_2^{'}$,..., $L_l^{'}$ to RGB space to get target lookup-tables. The flow chart is shown as Fig.4.

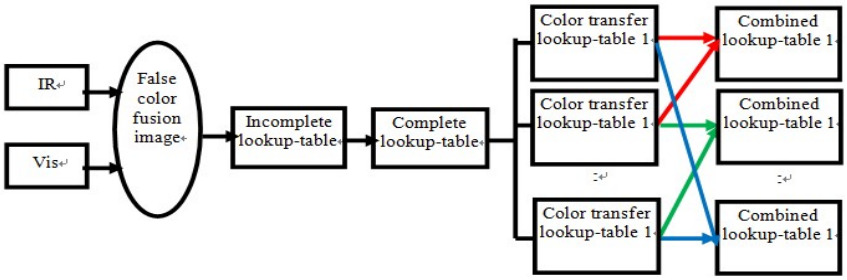


Fig.4 Flow chart of 2D color lookup-table based on multiple reference images

3.2 Double-band image colorize method based on multiple lookup-tables

Both TNO and BIT methods used direct assignment method when colorizing source images, it limits the choices of natural color by picking color values directly to the whole image from lookup-table. So this paper proposes a new method with selecting lookup-tables automatically to reduce the influence of a certain reference image. Steps are as follows:

Step1: (Define division size) Define a variable k and divide the source image into several pieces (record as *n*) with the size of *k*×*k*. Calculate the average values of each piece.

Step2: (Calculate average value) Calculate the average values of each combined color lookup-table respectively.

Step3: (Select lookup-table) Scan every piece of source image, calculate the differences of their average values and that of the lookup-tables' in turn, and select the minimize one to colorize each piece.

For the edge of source image, it may remain some areas that smaller than *k*×*k* and cannot be divided. The bigger the value of *k*, the bigger the area would be. So if the size of image is *m*×*n*, let *c* be the remainder of *k* divided by m while *d* be remainder of *k* divided by *n*, thus the size of edge should be *c*×*k* or *k*×*d*. The theory of colorize is shown as Fig.5.

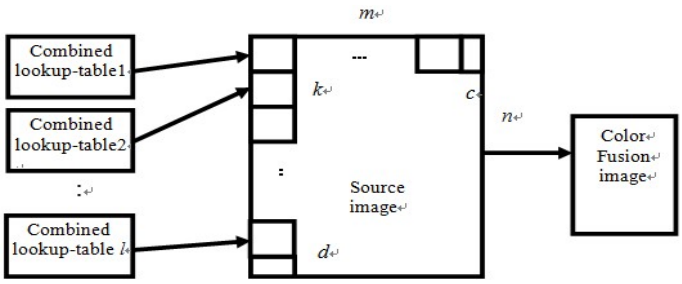


Fig.5 Image colorize based on multiple lookup-tables

4. Results of fusion experiments

4.1 Comparisons of the fusion images based on multiple reference images

To give more comparisons fairly, choose 6 pictures as reference images shown in Fig.6.

(1) (2) (3) (4) (5) (6)

Fig.6 Reference images

The paper will discuss the effects of different reference images and compare the fusion results when *k* changes. Fig.8 to Fig 10 are the fusion images of the method with two or three reference images, *k* equals to 3, 6, 9 in each picture.

(a)Visible image (b) IR image (c) False color fusion image

Fig.7 Source images

(a)*k*=3 (b)*k*=6 (c)*k*=9

Fig.8 Fusion images of Ref.(3)(4)

(a)k=3 (b)k=6 (c)k=9

Fig.9 Fusion images of Ref.(1)(2)(3)

(a)k=3 (b)k=6 (c)k=9

Fig.10 Fusion images of Ref.(3)(4)(6)

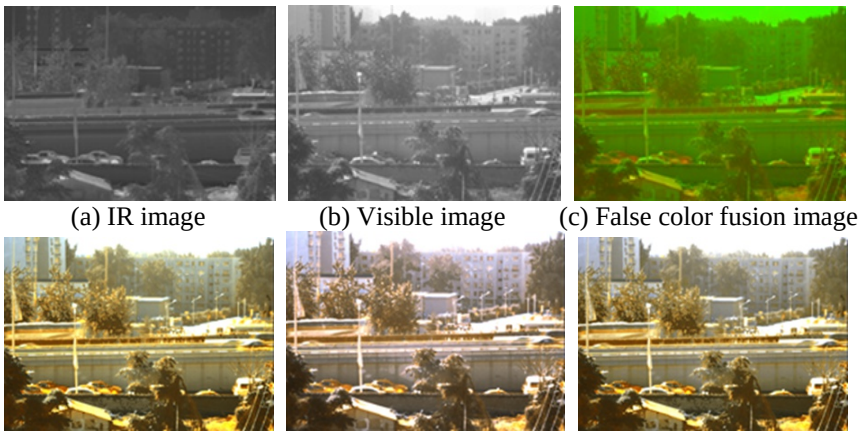
Compare the images in Fig.8, Fig.9 and Fig.10 vertically. All of the three groups of images get true and natural feeling color, they have the similar presentation on lights, trees, and buildings. Especially, they all used Ref.(3), which makes the road and buildings have natural color. In Fig.9, the yellow color is too heavy because of Ref.(2), while Fig.8 has more gentle performance with the help of Ref.(4). In general, Fig.14 and Fig.16 have better performance in natural color.

From the images in the three groups, when k equals to 3, 6, 9 respectively, the color distribution and natural feeling changes little, there are not obviously color boundaries or color pieces. That is because the lookup-tables are combined with several reference images and have smaller differences with each other.

The result shows that, using multiple reference images can make the color of fusion images get less influence from a certain reference image and have more stable color. The performance of natural feeling of fusion images is also better. The fusion results basically don't change greatly with k, and guarantee the reliable of color when doing partial operation.

4.2 Color fusion results in different scenes

Fig.11 and Fig.12 show two groups of color fusion results in different scenes, each group contains different combination of reference images.

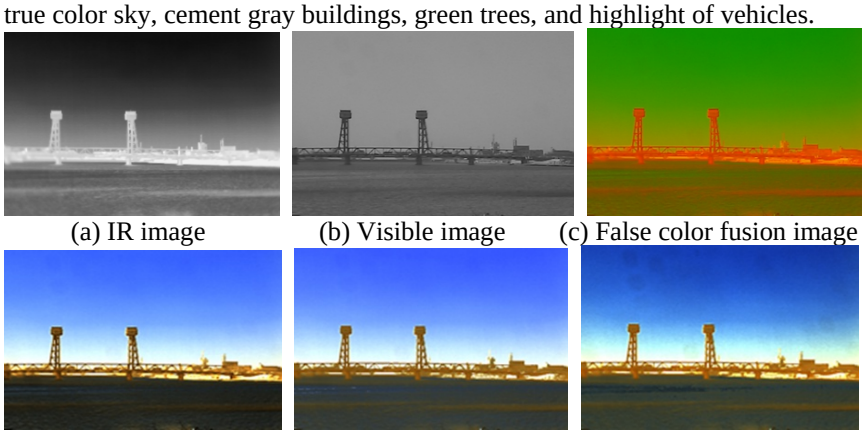


(a) IR image (b) Visible image (c) False color fusion image

(d) Result of Ref.(2)(3) (e) Result of Ref.(2)(3)(4) (f) Result of Ref.(1)(3)(4)

Fig.11 Color fusion experiment No.1

Fig.11 shows a scene of city at day time. Fig.11(d) and Fig.11(e) both contain the Ref.(2) and (3), so they have similar green trees and red vehicles. Because of the contribution of Ref.(4) in Fig.11(e), the color of buildings appears more gentle and true. On the whole, the three images can display natural color with a true color sky, cement gray buildings, green trees, and highlight of vehicles.



(a) IR image (b) Visible image (c) False color fusion image

(d) Result of Ref.(1)(3) (e) Result of Ref.(2)(3) (f) Result of Ref.(1)(2)(3)

Fig.12 Color fusion experiment No.2

Fig.12 shows a scene of sky and sea. The color of the sea in Fig.12(d) is the deepest under the effect of Ref.(1), while Fig.20(f) has the brightest color from Ref.(2). Overall, the performance of these three fusion images is satisfied, which changes little with reference images.

5. Conclusions

Based on the research of previous algorithms, this paper has put forward the multiple reference images based on lookup-table color image fusion algorithm and gained some innovation. The algorithm innovatively extracts a false color lookup-table from the false fusion image, thus built relationship with source image from the beginning. It used multiple reference images to establish color lookup-tables, and adopted division colorizing. According to the results of experiments, this algorithm has better performance on stability and authenticity of fusion images. It also reduced the dependence on a single reference image for fusion image, especially for complex scene.

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