Comparative Efficiency of Color Models for Multi-focus Color Image Fusion

Wirat Rattanapitak and Somkait Udomhunsakul

Abstract— **The comparative efficiency of color models for multi-focus color image fusion is presented in this paper. The objective of these experiments is to finding the proper color model for using in multi-focus color image fusion. In our research study, firstly we transform RGB color model of source images into four color models that are YIQ, YCbCr, HSV and HSI color models. Next, the intensity or luminance component is only used in fusion process using Spatial Frequency Measurement based fusion method compared with Stationary Wavelet Transform with Extended Spatial Frequency Measurement. Finally, the fused image results are transformed back to RGB model to get the final results. The experiments show that the YCbCr color model outperforms other color models in term of objective quality assessment.**

Keywords— Multi-focus image fusion, Color image fusion, Image color models

I. Introduction

Most fields in image processing require the accurate or reliable source image because the source images are very influence to analysis processes and result work. Nowadays, we can see many hi-tech equipments that are developed to solve this issues. As we well know, the equipment performances are increase, the cost of them are increasing too. Like a general digital camera, when a camera is to catch several objects that are indifferent distances, it could not be focused on these objects at the same time. To get a clear image containing all objects, we have two choices for solving this problem. Firstly, it is an easy way to use a hi-performance camera but it incurs for high cost. Secondly, we can apply an image processing technique, image fusion, which has been widely used in many fields such as medical imaging, remote sensing, computer vision and so on.

Multi-focus image fusion is an important process in digital image processing. The objective of image fusion is to combine an important data or target information that we want from two or more source images to obtain an image, which contains complete information. Recently, image fusion methods were continuously developed such as Multiresolution based fusion [1], Wavelet Transform based fusion [2] and Spatial Frequency Measurement based fusion [3]. Most of them perform on gray scale image but in the real world most images are color images leading to some multi-focus color image fusion were proposed [4,5]. Generally, color model of an image is RGB color model, which consists of three components, red component, green component and blue component. However, the RGB color model is not suitable for color image fusion because the correlation of the image channels is not clearly emphasized [4].

In this paper, we have presented the comparative efficiency of color models for multi-focus color image fusion. The comparison is implemented to perform on four color models that are YIQ, YCbCr, HSV and HIS. These components consist of three components. One is intensity or luminance and two color information or chrominance components. In this research study, the comparative efficiency of color models is performed on only intensity or luminance component of an image because intensity or luminance component is the weight average three color component of RGB image and it is less sensitive to noise [6].

The rest of this paper is organized as follow. In section 2, color model transformation is described. In section 3, two fusion methods are described. Then section 4, the comparative experiment is proposed. Finally, the experimental results and conclusion are presented in section 5 and 6, respectively.

II. Color Models Transformation

A color model or color space is a method by which we can specify, create and visualize color. There are three-dimensional arrangements of color sensations. Each color model may be useful for specific application. In general, there are a number of color models as following [6-8].

2.1 YIQ Color Model

YIQ is also as the same as NTSC color model. In this color model, Y represented the gray scale information component, while I and Q carry the color information. The transformation of RGB color model to YIQ color model can be derived as,

$$Y = 0.299R + 0.587G + 0.144B \quad (1)$$

$$I = 0.569R - 0.275G - 0.321B \quad (2)$$

$$Q = 0.212R - 0.523G + 0.311B \quad (3)$$

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2.2 HSV Color Model

HSV color model is wildly used to describe color perceived by human being. In this color model, intensity component is represented by V (Value), while H (Hue) and S (Saturation) carry color information. The transformation of RGB color model to HSV color model can be derived as following.

The normalized RGB values are obtained by:

$$r = \frac{R}{R+B+G}, g = \frac{G}{R+B+G}, b = \frac{B}{R+B+G} \qquad (4)$$

, which are in the ranges of [0,1].

Let MAX = maximum of (r,g,b) values and MIN = minimum of those values then,

$$R' = \frac{MAX - r}{MAX - MIN} \qquad (5)$$

$$G' = \frac{MAX - g}{MAX - MIN} \qquad (6)$$

$$B' = \frac{MAX - b}{MAX - MIN} \qquad (7)$$

$$S = \frac{MAX - MIN}{MAX} \qquad (8)$$

$$V = MAX \qquad (9)$$

$$H = (5 + B') \times 60 \rightarrow if\ r = MAX\ and\ g = MIN \qquad (10)$$

$$H = (1 - G') \times 60 \rightarrow if\ r = MAX\ and\ g \neq MIN \qquad (11)$$

$$H = (R' + 1) \times 60 \rightarrow if\ g = MAX\ and\ b = MIN \qquad (12)$$

$$H = (3 - B') \times 60 \rightarrow if\ g = MAX\ and\ b \neq MIN \qquad (13)$$

$$H = (3 + G') \times 60 \rightarrow if\ r = MAX \qquad (14)$$

$$H = (5 - R') \times 60 \rightarrow Otherwise \qquad (15)$$

2.3 HSI Color Model

This color model is an attractive color model for image processing applications because it represents colors similarly how the human eye senses colors [6]. In this color model, I is the intensity component, while H and S carry color information. The transformation of RGB color model to HSI color model can be derived as,

Let r, g and b are in the forms of normalized values (4)

$where\quad h \in [0, \pi]\ for\ b \le g$

$$h = \cos^{-1}\left\{ \frac{0.5[(r-g)+(r-b)]}{[(r-g)^2+(r-b)(g-b)]^{1/2}} \right\} \qquad (16)$$

$where\quad h \in [\pi, 2\pi]\ for\ b > g$

$$h = 2\pi - \cos^{-1}\left\{ \frac{0.5[(r-g)+(r-b)]}{[(r-g)^2+(r-b)(g-b)]^{1/2}} \right\} \qquad (17)$$

$$s = 1 - 3 \times MIN(r,g,b); \quad s \in [0,1] \qquad (18)$$

$$i = (R+G+B)/(3 \times 255)\ i \in [0,1] \qquad (19)$$

$then$

$$H = h \times 180/\pi; \quad S = s \times 100; \quad I = i \times 255$$

2.4 YCbCr Color Model

In this color model, intensity information component is represented by Y, while Cb and Cr are stored the color information. The transformation of RGB color model to YCbCr color model can be derived as,

$$Y = 65.481\,R + 128.553\,G + 24.966\,B + 16 \qquad (20)$$

$$Cb = -37.797\,R - 74.203\,G + 112.00\,B + 128 \qquad (21)$$

$$Cr = 112.00\,R - 93.786\,G - 18.214\,B + 128 \qquad (22)$$

III. MULTI-FOCUS IMAGES FUSION

3.1 Multi-focus Image Fusion Process

In multi-focus image fusion process, we used two methods that are SFM fusion based method [3] and extended SFM based method [9]. Especially, we perform the fusion process only in intensity or luminance component because in this component we can distinguish and determine the clearer focus in each image area. Also, the intensity or luminance component are noiseless than two color information components [6]. Image fusion processes of those methods are illustrated in figure 1 and figure 2, respectively.

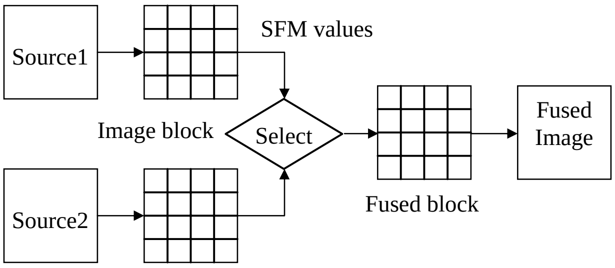

Fig. 1 SFM based fusion method

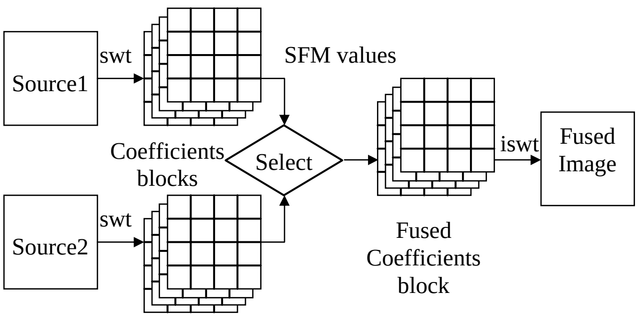

Fig. 2 Extended SFM based fusion method

From figure 1 and figure 2, we apply different three block sizes [4] as 4x4, 8x8, and 16x16 pixels. In figure 3, the different kinds of Mother Wavelet filters are used including orthogonal wavelet filter, db4, and four bi-orthogonal wavelet filters, bior2.2, bior3.3, bior3.5 and bior4.4 [4].

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3.2 Objective Fused Image Quality Assessment

In the experiments, we need to specify the suitable color models for color images fusion therefore we use a simple objective measurement, Peak Signal to Noise Ratio (PSNR), to evaluate the quality of fused color image. The PSNR is defined as below where MSE is referred to Mean-Square-Error.

$$PSNR = 10\log\frac{255^2}{MSE} \qquad (23)$$

IV. COLOR IMAGE FUSION

In this section, the fusion processes from section 3 are adopted for our experiments. The color image fusion on RGB color model and other color models, (YIQ, YCbCr, HSV, HIS) are shown in section 4.1 and 4.2, respectively.

4.1 Color image fusion on RGB Color Model

This is a simple fusion process because it is a normally color model of a color image. The fusion on RGB model can be performed by taking the corresponding each component of two tested images, each component of tested image1 is fused with each component of tested image2. In other words, we fused two source images in each component (red, green, and blue) separately. After we get the three fused components, the fused color image result came from three fused components as illustrated in the schematic, figure 3.

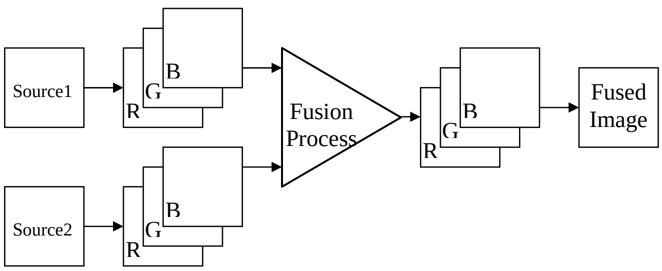

Fig. 3 Fusion process on RGB Color Model

4.2 Color image fusion on other color models

The fusion process on YIQ, YCbCr, HSV, HIS color models are similar to previous process. In these processes, we firstly transform RGB color model of tested images to our target color model. Then we do the fusion process only in intensity or luminance component. The process of these fusing can be described as following steps as illustrated in the schematic, figure 4.

1. Transform RGB color models of two tested images to target color models (YIQ, YCbCr, HSV, HIS)

2. In each target color model, the intensity or luminance components of two tested images are used in fusion process.

3. The fused intensity component form step 2 is used as intensity or luminance of fused image result.

4. The color information of two tested images are compared and chosen from the clear or sharp area.

5. Inverts all components to get a fused image result in RGB model.

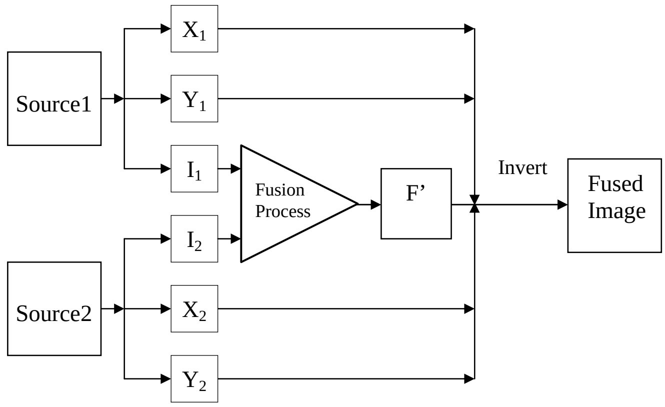

Fig. 4 Fusion process on other color models

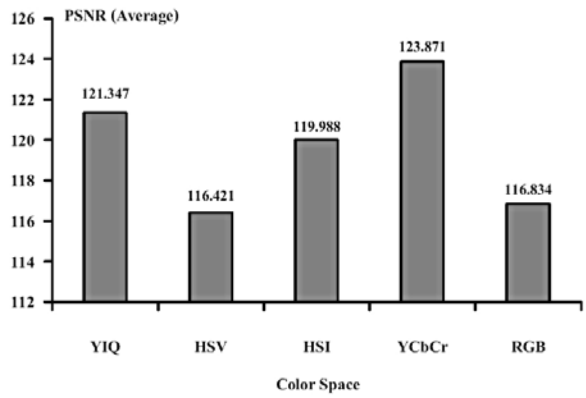

Fig. 5 Fused image quality assessments in each color model

V. EXPERIMENTAL RESULTS

Twelve RGB, 24 bits, color image sources of different sizes are used in our experiments shown in figure 8. Also, two fusion processes in section 3 are compared using the block sizes 4x4, 8x8, and 16x16 pixels. For extended SFM based fusion method [9], mother wavelets db4 and four bi-orthogonal wavelet filters tbior2.2, bior3.3, bior3.5 and bior4.4 are adopted. Therefore, each image is totally fused and provided 15 fused image results. The image qualities of fused image results are compared and evaluated by using PSNR. In table 1, it shows the best PSNR values chosen from 15 fused image results in each color image source. Moreover, figure 5 presents a graph of the average PSNR values from table 1.

5.1 Comparison in each color model results

Figure 5 shows the average fusion results of twelve tested images obtained from five color models as shown in Table 1. As can be seen, the results of YCbCr color model gives the best results in term of objective assessments, PSNR.

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5.2 Comparison of color image fusion methods

The results of two color fusion methods are shown in Table 2. We can see that the extended SFM based method [9] is slightly better than traditional SFM based method [4] in term of objective assessment using PSNR. In subjective assessment, the fused images using SFM based method are contained blocking artifacts [4]. In addition, they are suffered from uneven gray level compared to the original images [9].

TABLE I
THE BEST PSNRS EVALULATED FROM EACH COLOR MODEL

Source Set No.	Best PSNRs in Each Color Space				
	RGB	**YIQ**	**HSV**	**HSI**	**YCbCr**
1	114.12	119.01	116.16	116.90	***121.54***
2	122.96	134.89	123.68	130.85	***137.17***
3	124.66	135.25	125.25	130.58	***137.22***
4	120.92	125.48	121.55	123.87	***127.94***
5	115.60	117.64	115.54	116.86	***120.18***
6	103.21	111.01	101.84	108.05	***113.63***
7	110.88	116.08	111.94	113.65	***118.65***
8	108.66	110.60	107.17	109.86	***113.22***
9	111.66	114.74	111.86	113.66	***117.31***
10	132.73	133.74	128.86	133.43	***136.39***
11	137.32	140.20	133.69	142.28	***142.81***
12	114.89	118.39	114.50	117.15	***120.94***

VI. CONCLUSION

In this paper, the comparative efficiency of color models for color multi-focus image fusion is presented. In our experiments, five color models (RGB, YIQ, YCbCr, HSV, HIS) are compared as well as two fusion methods, SFM fusion based method and extended SFM based method. The results show that the suitable color model for color image fusion is YCbCr. In our research study, we consider only in intensity or luminance component because this component is the most effectively to get the fused image results. Moreover, our studies are useful and practical way to select the optimize color model for any applications. In the future works, the effects of color information or chrominance components for multi-focus color image fusion will be studies.

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TABLE II
RESULTS FROM SFM BASED METHOD AND EXTENDED SFM BASED METHOD

Source Set No.	Best PSNRs in Each Color Space									
	SFM method					SWTSFM method				
	RGB	YIQ	HSV	HSI	YCbCr	RGB	YIQ	HSV	HSI	YCbCr
1	113.963	118.764	115.936	116.704	121.305	114.107	119.015	116.163	116.909	***121.548***
2	122.402	133.581	124.489	129.971	136.068	122.964	134.898	123.681	130.850	***137.174***
3	124.243	134.450	124.599	130.054	136.525	124.660	135.257	125.258	130.589	***137.225***
4	120.349	124.232	120.998	123.414	126.937	120.928	125.480	121.550	123.876	***127.946***
5	114.702	116.552	114.736	115.920	119.122	115.601	117.644	115.542	116.863	***120.188***
6	102.995	110.557	101.732	107.830	113.164	103.217	111.014	101.845	108.051	***113.630***
7	110.820	115.977	111.888	113.624	118.544	110.885	116.088	111.947	113.654	***118.657***
8	108.725	110.682	107.190	109.919	113.295	108.662	110.607	107.175	109.864	***113.222***
9	111.318	114.172	111.514	113.231	116.760	111.661	114.749	111.860	113.661	***117.314***
10	131.744	132.728	127.527	132.524	135.470	132.735	133.746	128.867	133.430	***136.390***
11	135.309	137.148	132.958	138.566	139.647	137.322	140.208	133.692	142.280	***142.814***
12	114.895	118.367	114.496	117.140	120.920	114.898	118.394	114.501	117.158	***120.948***

(a) Reference image (b) Source image; focus on right (c) Source image; focus on left

Fig. 6 An example of tested images

(a) Fused image result of RGB model (b) Fused image result of YIQ model (c) Fused image result of YCbCr model

Fig. 7 Fused image results of three color models

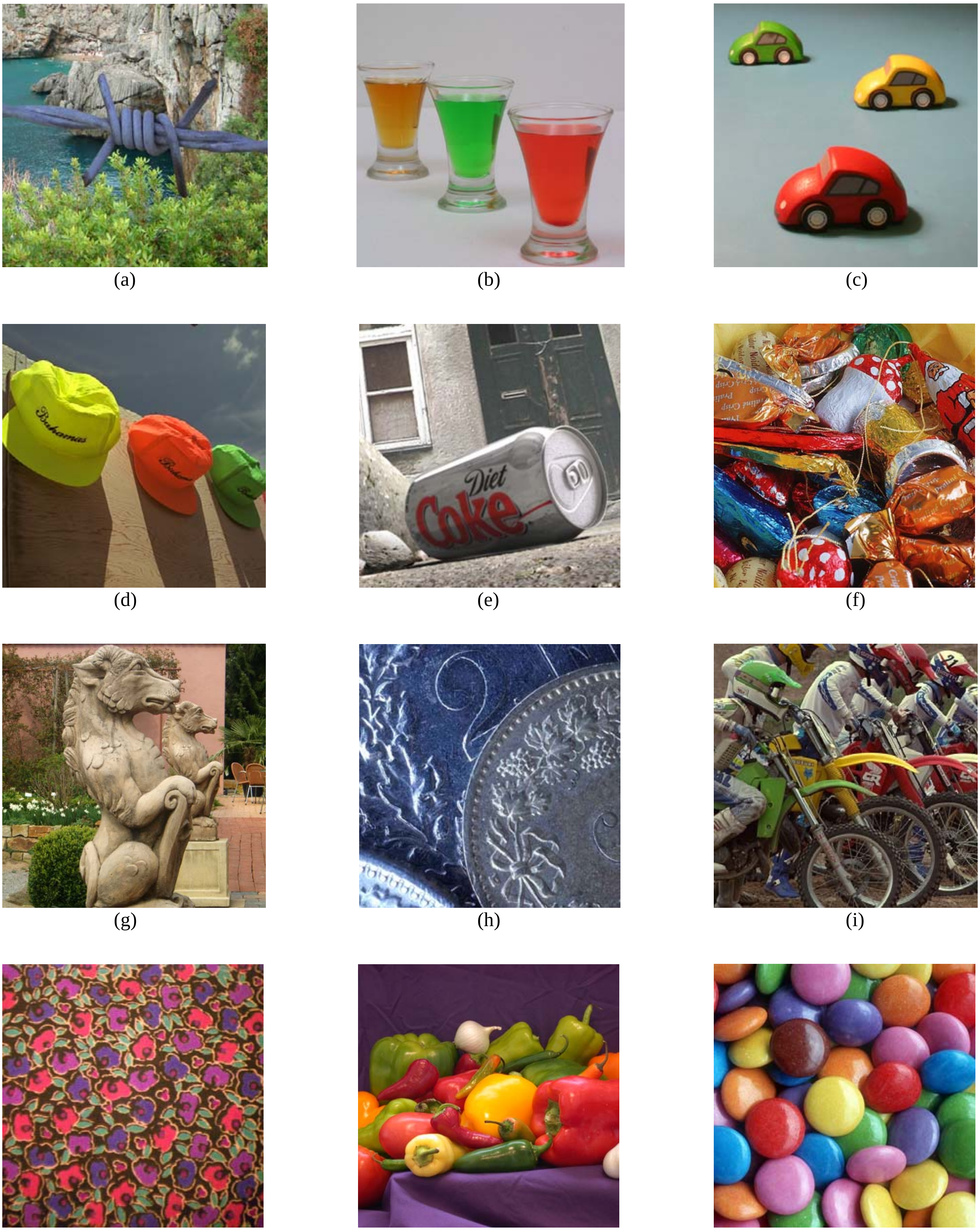

Fig. 8 Twelve tested images for color image fusion

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