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Comparative Assessment of Color Models for Multi-Focus Image Fusion With Optimal Cluster Size

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Abstract**—** This paper assesses comparatively the performance of image fusion in different color channels using an image matting based multi focus image fusion technique, the JR method. This is a solely vicinity-based image matting algorithm that relies on the close pixel clusters in the input images. Color spaces provide powerful information for image processing by means of color variants, color histogram, color texture etc.. In our assessment, firstly we transform RGB color model of multi focus source images in to 6 different color spaces that are HSV, L*a*b, YUV, YIQ, YCbCr and XYZ. Next, each color channel of input images (RGB-R, RGB-G, RGB-B, LAB-L, LAB-A, LAB-B, HSV-H, HSV-S, HSV-V, YUV-Y,YUV-U, YUV-V, XYZ-X, XYZ-Y,XYZ-Z, YCbCr-Y, YCbCr-Cb, YCbCr –Cr, YIQ-Y, YIQ-I, YIQ-Q) are used in fusion process using the image matting based multi focus image fusion with optimal cluster size (the JR method). Finally the fused images are assessed with standard image quality metrics. The results certainly show better results in LAB-L and YIQ-Q color channals.

Keywords**—** Color spaces, Multi focus image fusion, image color models, color image fusion**.**

I. Introduction

The aim of image fusion is to improve the understanding of a scene by blending significant information that can be collected from the noticed scenery captured by same or different sources at the same or different times.

The need of image fusion in image processing domain is on the rise due to the propagation of multi-sensor, multi-temporal, multi-resolution and multi-view image data. Current technology in imaging sensors presents a wide variety of different information that can be extracted from an observed scene [1]. However, imaing sensors may have few limitations such as optical degradations and narrow resolution efficiency. Moreover, the noticed scenary may not be stabel due to object motion and media unrest. Hence, the captured images may often get blurred, display insufficient spacial and/or temporal resolution. Such images are not suitable for visual judgement or further processing. Thus the requirement for fusion of digital images are now higher than ever before.

Image fusion prompts the synergistic integration of suitable information from a set of images, into a single composite image making the output more descriptive and enabling improved performance for detection, visualization or classification tasks.

II. RELATED WORK

Many image fusion methods are developed in the past decades [2]. The image fusion algorithms have been categorized into pixel, feature and decision levels [3] based on the portrayal at which image information is handled. Pixel level image fusion is the process of obtaining information based on the pixel strength from more than one images of the same scene to get legitimate inputs which helps in further image processing. Such methods blend more than one input images into a single combined image in a raw image protraint andd more real information compared with feature and decision-level methods.

Since it exists a lot of color spaces, it is useful to classify them into a few categories with respect to their definitions and their properties.

- The primary spaces aree based on the trichromatic theory which assumes that it is possible to match any color by mixing an appropriate amount of the three primary colors. The primary space used in the proposed assessment is the real primay color space RGB.

- The luminance chrominance spaces are compounded of one color component which represents the luminance and of two color components which represent the chrominance. The luminance-chrominance space used in the proposed assessment is L*a*b.
- The HSV (hue, saturation, value) is one of the several color systems used by people to select colors from a color wheel or palette. In artists' terminology, hue, saturation and value refer approximately to tint, shade and tone.

The basic idea of selecting and implementing an image matting based multi-focus image fusion with optimal cluster size, the JR method [4] in HSV, L*a*b, YUV, YIQ, YCbCr and XYZ color space was to perform a comparative study on the performance of the algorithm in different color spaces. The results were compared based on image quality performance metrics such as Structural Similarity Index (SSIM), the gradient based matric $Q^{AB/F}$, Universal Image Quality Index (UIQI) and Peak Signal Noice Ratio (PSNR). The objective is to identify which color channel renders better results for the JR method in RGB, HSV, L*a*b, YUV, YIQ, YCbCr and XYZ color spaces.

The rest of the article is organized as follows. In section III, color model transformation is described. In section IV, the JR method is explained. Experiment results with the image quality metrics and performance assessment are presented in section V. The assessment results are concluded in section VI.

III. COLOR MODELS

The most popular color space in color image processing is the RGB color space, where a color point in this space is recognized by the color component levels of the corresponding pixel, namely the red (R), the green (G) and the blue (B).

The HSV color space is motivated by the human vision system in the sense that human describes color by means of hue, saturation, and brightness. Let MAX = max(R,G,B), MIN = min(R,G,B), and δ = MAX−MIN, the HSV color space is defined as follows [5]:

$$V = Max$$

$$S = \delta/Max$$

$$H = \begin{cases} 60(G-B)/\delta \text{ if } Max = R \\ 60(B-R+2\delta\delta)/ \text{ if } Max = G \\ 60(R-B+4\delta\delta)/ \text{ if } Max = B \end{cases} \quad -(1)$$

The L∗a∗b∗ color space is modeled based on human vision system and is defined as follows [5]:

$$L = 116\, f(Y/Y_0) - 16$$
$$a^* = 500\,[f(X/X_0) - f(Y/Y_0)] \quad -(2)$$
$$b^* = 200\,[f(Y/Y_0) - f(Z/Z_0)]$$

where

$$f(x) = x^{1/3} \text{ if } x > 0.00856;$$
$$f(x) = 7.787x + 16/116 \text{ otherwise}$$

The YUV and YIQ color models are generally used in video for transmission efficiency. The YIQ color space is adopted by the NTSC (National Television System Committee) video standard in reference to RGB NTSC. In YUV, Y is the luminance (brightness) component while U and V are the chrominance (color) components. The YUV color space is defined as follows [5].

$$\begin{bmatrix} Y \\ U \\ V \end{bmatrix} = \begin{bmatrix} 0.2990 & 0.5870 & 0.1140 \\ -0.1471 & -0.2888 & 0.4359 \\ 0.6148 & -0.5148 & -0.1000 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad -(3)$$

The YIQ color model is used by the PAL (Phase Alternation by Line) and the SECAM (System Electronique Couleur Avec Memoir). The YIQ color space is specified as follows [5].

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.2990 & 0.5870 & 0.1140 \\ 0.5957 & -0.2745 & -0.3213 \\ 0.2115 & -0.5226 & 0.3111 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad -(4)$$

The YCbCr color space is a scaled and offset version of the YUV color space. The Y channel has 220 levels ranging from 16 to 235, while the Cb, Cr components have 225 levels ranging from 16 to 240:

$$\begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} = \begin{bmatrix} R \\ G \\ B \end{bmatrix} + \begin{bmatrix} 65.4810 & 128.5530 & 24.9660 \\ -37.7745 & -74.1592 & 111.9337 \\ 111.9581 & -93.7509 & -18.2072) \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad -(5)$$

where the R,G,B values are scaled to [0,1].

XYZ color space[5] was created by the International Commission on Illumination (CIE) in 1931.The CIE XYZ color space encompasses all color sensations that are visible to a person with average eyesight.

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 0.607 & 0.174 & 0.200 \\ 0.299 & 0.587 & 0.114 \\ 0.000 & 0.066 & 1.116 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad -(6)$$

IV. METHODOLOGY

The JR multi focus image fusion method is a noval cluster based image fusion algorithm that involes the computation of alpha matting of multi focus images. Image matting is an important technique to precisely locate the foreground from background [6] which has been used in many applications. Given a trimap of known foreground / background and unknown pixels, a straightforward way to calculate the alpha (***α***) value is to sample few known foreground and background colors for each unknown pixel. The alpha blending is mathematically defined in such a way that at every pixel of the image, the foreground image and the background image are combined using the alpha mask (***α***)***.*** The fused image can be viewed as a combination of foreground and background.

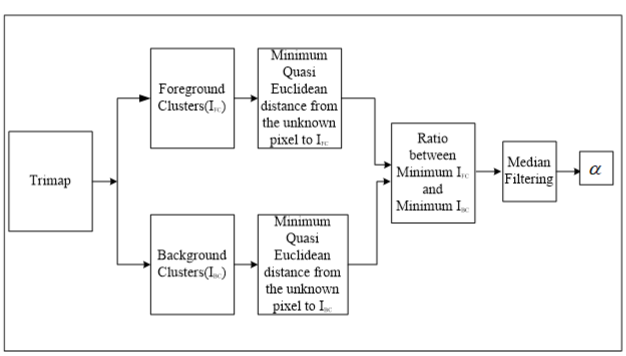

Figure 1: System Chart showing the Cluster based Image Fusion Method (JR Fusion Method)

Algorithm: JR MFIF method.
Step 0: Given multi-focus images ***I_1, I_2*** of the same scene **Step 1:** Obtain focus information of the images by morphological filtering operator. **Step 2 :** Identify the definite focused and defocused regions by comparing the focus value of each pixel **Step 3:** Obtain ***R_1*** and ***R_2*** maps by comparing the focus value of each pixels **Step 4:** Apply median filtering and skeletionization on ***R_1*** and ***R_2*** to get definite focused region. **Step 5:** Compare each pixel in ***R_1*** and ***R_2*** maps to get *trimap* ***T*** that has three segmented regions as foreground, background and unknown region. **Step 6:** Find the clusters of N x N window for the foreground pixels and background pixels. **Step 7:** Find the distance of each undefined pixel from foreground and background clusters. **Step 8:** Calculate the minimum distance of each pixel from foreground and background clusters. **Step 9:** Ratio between minimum distance of foreground and background of each pixel gives the alpha matte of the corresponding pixel. **Step 10:** The fused image is obtained by the following fusion process. $I_f(x, y) = \alpha(x, y)I_1(x, y) + (1 - \alpha(x, y)I_2(x, y)$ Where ***$I_F(x,y)$*** is the fused image***,*** ***$\alpha(x,y)$*** is alpha matte, ***$I_1(x,y)$*** and ***$I_2(x,y)$*** are the multi focus input images.

N – Analysis

In the proposed assessment, the quality of the fused image in each color channel varies depending on the size of the cluster N. The qualitative aspect is studied by using 'N-Analysis' in the present work. N value can be changed from one set of image data sets to another set. Therefore in the present work, N value is plotted against each one of the performance metrics and the optimal N value is found. This N value is used to obtain the fused image.

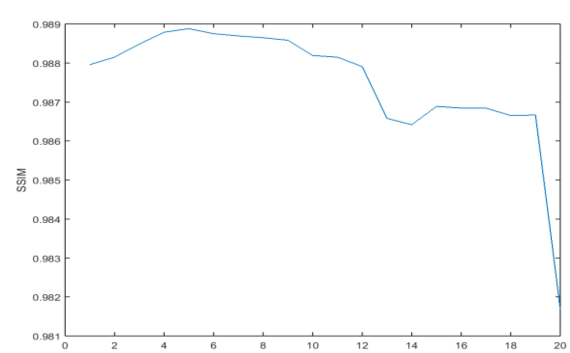

Figure 2: N-Analysis

Performance Metrics

The image quality performance metrics such as, (i) Structural Similarity (SSIM) which reveals the degree of structural similarity between two images in luminance, contrast and structure, [7] (ii) QAB/F , which reflects the amount of edge information transferred from the source images ($\boldsymbol{I_1}$, $\boldsymbol{I_2}$) to the fused image ($\boldsymbol{I_F}$) [8] (iii) an Universal Image Quality Index (UIQI) that models any distortion as a combination of three different factors: loss of correlation, luminance distortion and contrast distortion, [9] (iv) Peak Signal-Noise Ratio (PSNR), the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation; are evaluated for the fusion methods and the results are recorded.

The JR multi focus image fusion technique was performed on 5 pairs of multi focus image set. Each image set consists of 3 images wherein the first two images were source images with different objects in focus and the third image was used as reference all-in-focus image. The JR fusion technique was performed on 21 color channels. They are RGB-R, RGB-G, RGB-B, LAB-L, LAB-A, LAB-B, HSV-H, HSV-S, HSV-V, YUV-Y,YUV-U, YUV-V, XYZ-X, XYZ-Y,XYZ-Z, YCbCr-Y, YCbCr-Cb, YCbCr –Cr, YIQ-Y, YIQ-I, YIQ-Q.

GUI Architecture

The math works MatLab R2015a is used to develop programs for the fusion of different color channels described in the assessment.

A convenient GUI is developed for the execution of JR fusion technique on different color channels and quality metrics. The Figure 3 shows the snapshot of the GUI window of the color assessment system designed and developed during the present research work.

Figure 3: GUI Architecture for Comparative Assessment of Color models for multi-focus image fusion with optimal cluster size

The two input images I_1 and I_2 that are supposed to be fused can be easily browsed through two buttons namely *Input image 1* and *Input image 2*. The reference image I_R is required for certain quality metrics such as SSIM, RMSE etc.. Hence reference image I_R is chosen using *Reference image* button. The panel Color Channels in Figure 3 at the left bottom of the GUI has access to the individual color channels of the input images that are developed during the present study. By selecting the radio button, corresponding color channel is executed in JR fusion technique and the resultant fused image is displayed on the third axes. When *Save Images* button is clicked, the input images and fused images are saved in a specific folder with specific file names. The folder and file names are named after the selected color channel and selected dataset, dynamically.The quality metrics such as SSIM, PSNR, QAB/F and QI are calculated for the selected color channel in JR fusion technique and their values are displayed in the *Performance Metrics* panel of the GUI window. When *Save Performance Metric* button in pannel is selected, the computed values of four metrics are stored in MS-Excel file and displayed in the panel also. The file is named dynamically as "Performance_metric_datasetname".

The proposed assessment is analysed by changing the cluster size. The resultant N graph is displayed in *N-Analysis* panel. The optimal N-value is used as the size of the structural element. The cluster size (N) of the JR method is varied to obtain its optimal size while the value of a performance metric is high. Here the SSIM metric is plotted against the value of N ranging from 1 to 20. This plot is drawn in N Analysis panel when the particular color channel is selected. From the N graph, the optimal N value is found and displayed on the N-Analysis panel. This optimal N value is used to obtain the resultant fused image on the selected color channel. By default, the resultant image is obtained by using the optimal N value observed from N-graph of SSIM versus N. The N-Analysis is carried out based QAB/F where reference image is not involved. When *create chart* button is clicked over, a grouped bar chart is created, that can give a comparison of all performance metrics for each input set in the JR Fusion method.

V. RESULTS AND DISCUSSION

In order to assess the performance of different color channels in JR multifocus image fusion method, experimental methods are performed on 5 pairs of multi focus images.The images are taken in 21 color channels (RGB-R, RGB-G, RGB-B, LAB-L, LAB-A, LAB-B, HSV-H, HSV-S, HSV-V, XYZ-X, XYZ-Y, XYZ-Z, YUV-Y,YUV-U, YUV-V, YIQ-Y, YIQ-I, YIQ-Q, YCbCr-Y, YCbCr-Cb, YCbCr–Cr) Experiments are conducted with MatLab R2015a in windows environment of a computer with Intel i5 and 4 GB memory.

The source multi focus image data sets (Book, Doll, Jug, Golf and Statue) in 21 color channels are constructed for testing the JR fusion method. The fused images and the results of one dataset (book) for various performance metrics has been displayed in Figure 4.

Figure 4 : Fused Images : (A) - RGB-R, (B) - RGB-G, (C) - RGB-B, (D) - LAB-L, (E) - LAB-A, (F) - LAB-B, (G) - HSV-H, (H) - HSV-S, (I) - HSV-V, (J) - XYZ-X, (K) - XYZ-Y, (L) - XYZ-Z, (M) - YUV-Y, (N) -YUV-U, (O) - YUV-V,
(P) - YIQ-Y, (Q) - YIQ-I, (R) - YIQ-Q, (S) - YCbCr-Y, (T) - YCbCr-Cb, YCbCr –Cr

Performance Metrics chart

The qualitative analysis is done by computing four different performance metrics such as SSIM, QAB/F, QI and PSNR. The values of the metrics for the book data set is plotted and tabulated in the below chart and table respectively.

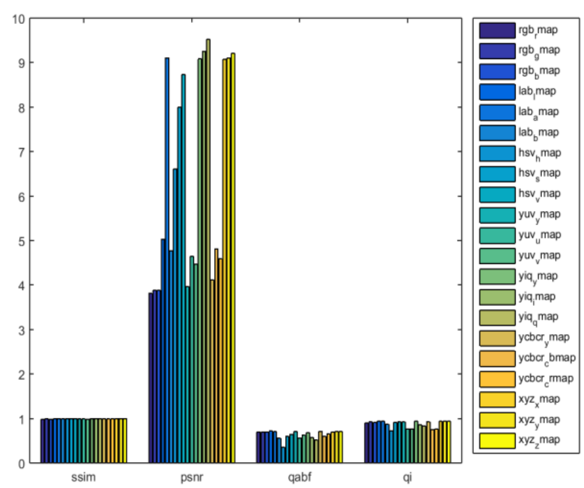

Figure 5: Performance Metrics Chart for Book Data set

Table 1: The values of four performance metrics (SSIM, QAB/F, QI and PSNR) for the different color channels

Color map	SSIM	Qabf	QI	PSNR
RGB-R	0.984348	0.984348	0.905728	3.808135
RGB-G	0.989323	0.989323	0.919632	3.881310
RGB-B	0.985713	0.985713	0.913734	3.885052
LAB-L	0.998114	0.998114	**0.943628**	5.032053
LAB-A	0.999997	0.999997	0.938871	9.107177
LAB-B	0.989659	0.989659	0.866673	4.765731
HSV-H	0.999355	0.358286	0.721631	6.612134
HSV-S	0.999963	0.593719	0.916209	7.995952
HSV-V	0.999993	0.646912	0.924631	8.738744
YUV-Y	0.992675	0.709548	0.922889	3.962527
YUV-U	0.988505	0.562359	0.769401	4.646064
YUV-V	0.986311	0.620900	0.771375	4.471013
YIQ-Y	0.999996	0.685027	0.941517	9.082875
YIQ-I	0.999998	0.570713	0.855689	9.254715
YIQ-Q	**0.999999**	0.511769	0.831894	**9.524192**
YCbCr-Y	0.994449	0.714633	0.920124	4.115397
YCbCr-Cb	0.991679	0.604119	0.752013	4.815626
YCbCr-Cr	0.988880	0.652563	0.764904	4.586274
XYZ-X	0.999997	0.697663	0.939353	9.069237
XYZ-Y	0.999997	0.707264	0.938871	9.107177
XYZ-Z	0.999998	0.703336	0.935002	9.210960

It is evident from the tables that the fusion effect is obviously superior in color channel LAB-L and YIQ-Q in most of the input data set. The main reason is that the JR method effectively identifies the strengths of the pixels by its vicinity understanding algorithm in LAB-L and YIQ-Q color channel, preserving the texture and edge features of the source images clearly, and removing the artifacts in the fused image.

VI. CONCLUSION

This research article assessed comparatively the performance of image fusion in 21 color channels using an image matting based multi focus image fusion algorithm (The JR fusion method). In particular, the color channels RGB-R, RGB-G, RGB-B, LAB-L, LAB-A, LAB-B, HSV-H, HSV-S, HSV-V, YUV-Y,YUV-U, YUV-V, XYZ-X, XYZ-Y,XYZ-Z, YCbCr-Y, YCbCr-Cb, YCbCr –Cr, YIQ-Y, YIQ-I, and YIQ-Q have been comparatively assessed by fusing 5 sets of multi focus images. The results have been assessed systematically with the standard image quality metrics and the experimental results shows that some color channels, such in LAB-L and YIQ-Q yields better results, help improve fusion process for the image matting based multi focus image fusion algorithm.

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