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Research Article

Improved Multidimensional Color Image Fusion Based on the Multi-Wavelets

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Abstract: Image fusion refers to the process of combining the visual information present in two or more images into a single high information content image. This study proposes the concept of fusing the Multi-dimensional images using the YCbCr color model based on the Multi-Wavelet Transform (MWT). Initially the source images namely the visible, Infra Red (IR) and Ultra Violet (UV) images are transformed from RGB color model to YCbCr color space and then MWT is applied to the Y, Cb and Cr components of the respective images. Finally the transform coefficients obtained are fused using the different fusion techniques. The performance of the color image fusion process is analyzed using the performance measures-Entropy (H), Peak Signal to Noise Ratio (PSNR), Root Mean Square Error (RMSE) and Correlation Coefficient (CC).

Keywords: Entropy (H), multi-dimensional images, Multi-Wavelet Transform (MWT), Root Mean Square Error (RMSE), YCbCr color space

INTRODUCTION

Image processing finds its application in various areas and requires reliable and accurate source images for obtaining efficient result work, proposed by Smith and Heather (2005). Due to the advancement in technology, many types of equipment are used now days for getting detailed information of objects of interest in an image. Since the information content varies with image, it is not possible to get all the information content in a single image. Several researchers worked on the fusion of the images using several techniques such as wavelet transform based fusion, Multiresolution based fusion and spatial frequency based image fusion. Hence, the image fusion has several applications in remote sensing, medicine, computer vision and robotics, military and so on, presented by Chandrakanth *et al*. (2011), Anna *et al*. (2006) and Luo *et al*. (2011). Most of the image fusion techniques proposed focus on the fusion of gray scale images but in the real world most of the images are color images. So, researchers start focusing on the fusion of Multidimensional color images in order to increase the information content on the images for further research analysis.

Multi-dimensional image fusion is an important aspect in digital image processing, as discussed by Lawrence *et al*. (2011). Several color models were proposed for the fusion of color images namely RGB, HIS, YIQ, HSV and YCbCr. Generally a color image consists of Red, Green and Blue components. However, the RGB color model is not suitable for color image fusion since the correlation of the image channels is not clearly emphasized. Among all the color models it has been observed that YCbCr color model has higher efficiency. In our present study, both the luminance and chrominance components are used for the fusion process. The objective of our study is to combine the variable information present in the different source images into a single image with improved information content and also to improve the color content present in the images for further research analysis.

MULTI-WAVELET TRANSFORM

Due to the limitation in the Time-frequency localization property of the wavelet transform, MWT has been used extensively for several applications in the recent years, as presented by Hai-Hui *et al*. (2005) and Yuanning *et al*. (2010). Multiwavelets have two or more scaling and wavelet functions. Multiwavelets have several applications in image processing namely image compression, watermark processing, image pattern recognition, image denoising and so on, is discussed by Liu (2011) and Leelavathy *et al*. (2011). The multiscaling function is defined from the set of scaling functions as:

$$\Phi(t) = [\varphi_1(t)\ \varphi_2(t)\ \ldots\ \varphi_r(t)\ ]^T \tag{1}$$

Similarly the multiwavelet function is defined from the set of wavelet functions as

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$$\Psi(t) = [\psi_1(t)\ \ \psi_2(t)\ \dots\ \psi_r(t)]^T \quad (2)$$

where, r > 1 is an integer. When r = 1, is called a scalar wavelet or simply wavelet. When r = 2, is called a multiwavelet. The multiwavelet two scale equations are denoted by:

$$\Phi(t) = \sum_{k=0}^{m-1} G_k \Phi(2t-k) \quad (3)$$

$$\Psi(t) = \sum_{k=0}^{m-1} H_k \Phi(2t-k) \quad (4)$$

The pair $\{G_K, H_K\}$ is called a multiwavelet filter bank. G_K is called a matrix low pass filter and H_K is called a matrix high pass filter. They are r×r matrices for each integer k and m is the number of scaling coefficients. Multiwavelets have remarkable properties namely orthogonality, symmetry, short support and vanishing moments which are known to be important in image processing.

MATERIALS AND METHODS

The hyper spectral image of the flowers used as the source images for the fusion process are obtained from the site naturfotograf.com and the experimental studies were carried out in the Image Processing laboratory of the School of Electrical and Electronics Engineering, Sastra University, Thanjavur, India on January 2012. The multispectral fusion process is implemented using the Matlab R2010a software.

Pre-processing: Initially, the image registration process is performed on the source images namely the visible, UV and IR images respectively. Then noise removal is carried out on the source images using the median filter.

YCbCr color SPACE: In this model, Y stands for Luminance, Cb represents the blue chroma and Cr represents the red chroma. YCbCr is a scaled and offset version of the YUV color space, proposed by Phung *et al*. (2002), Wirat and Somkait (2010) and Surbhi *et al*. (2010). The principal advantage of the model in image processing is decoupling of luminance and color information. The importance of this decoupling is that the luminance component of an image can be processed without affecting its color component. Fast computation is the other major advantage of YCbCr color space, proposed by Ali and Sedigheh (2011) and Guangxin (2011). In our present study, the source images are transformed from RGB color model to YCbCr color model. The transformation from the RGB color model to YCbCr color space is expressed as:

$$Y = 65.481R + 128.553G + 24.966B + 16 \quad (5)$$

$$Cb = -37.797R - 74.203G + 112.00B + 128 \quad (6)$$

$$Cr = 112.00R - 93.786G - 18.214B + 128 \quad (7)$$

Multidimensional color image fusion algorithm:

- Transform the registered source images from RGB color model to YCbCr color space. Both the luminance and chrominance components are used for the fusion process.
- Apply Multi-Wavelet Transform to the Y, Cb and Cr components and MWT coefficients are generated (Fig. 1).
- The Select Maximum fusion rule or any other rule (Average, PCA and Laplacian pyramid) is used for the fusion of the coefficients.

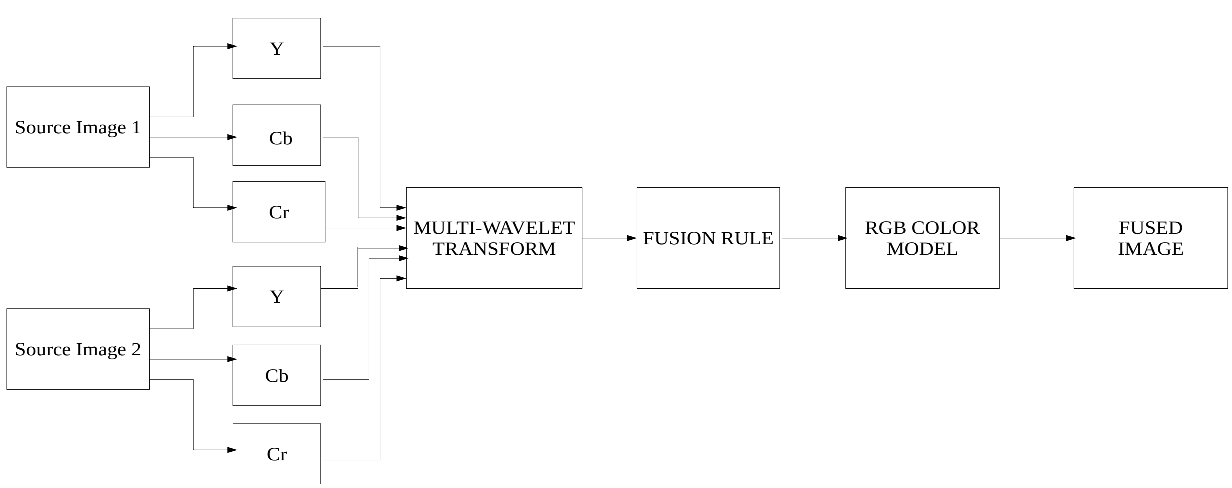

Fig. 1: YCbCr color space multidimensional image fusion based on MWT

- Apply Inverse MWT to the fused coefficients and transform the fused coefficients from the YCbCr color space to the RGB color space to obtain the fused image.

IMAGE FUSION RULES

Some of the image fusion rules used in our present study is discussed below:

Select maximum method: In this method, the pixel with maximum intensity is selected and used as the resultant pixel of the fused image for every corresponding pixel of the input images.

Average method: In this method, the resultant fused image is obtained by taking the average of the average of every corresponding pixel in the input images.

Principal Component Analysis (PCA) method: This is a statistical method for transforming a multivariate data set with correlated variables into a data set with new uncorrelated variables presented by Patil and Mudengudi (2011), Jinzhu *et al*. (2011) and Manjusha and Udhav (2010). For this purpose search is made of an orthogonal linear transformation of the original N-dimensional variables such that in the new coordinate system the new variables be of a much smaller dimensionality M and be uncorrelated. In the Principal Component Analysis (PCA) the sought after transformation parameters are obtained by minimizing the covariance of error introduced by neglecting N-M of the transformed components.

Laplacian pyramid method: Laplacian pyramid of an image is a set of bandpass images, in which each is a bandpass filtered copy of its predecessor ,proposed by Se-Hwan *et al*. (2010), Scott and Pusateri (2010) and Indhumadhi and Padmavathi (2011). Band pass copies can be obtained the difference between lowpass images at successive levels of a Gaussian pyramid. The basic idea is to construct the pyramid transform of the fused image from the pyramid transforms of the source images and then inverse pyramid transform is performed to obtain the fused image.

PERFORMANCE MEASURES FOR IMAGE FUSION

Several performance measures are used to estimate the performance of the image fusion process, presented by Malviya and Bhirud (2010). In the present study, four performance measures are used to evaluate the effectiveness of the color image fusion algorithm.

Entropy (H): Entropy is a measure of the average information content in an image. Higher the value of entropy indicates higher information content in the image. The entropy is denoted by:

$$H = -\sum_{g=0}^{L-1} p(g)\log_2 p(g) \tag{8}$$

Root Mean Square Error (RMSE): The RMSE between a reference image, R and a fused image, F, is given by the following equation:

$$RMSE = \sqrt{\frac{1}{MN}\sum_{m=1}^{M}\sum_{n=1}^{N}\left(R(m,n)-F(m,n)\right)^2} \tag{9}$$

where, R (m, n) and F (m, n) are the reference (visible image) and fused images, respectively and M and N are image dimensions. Smaller the value of the RMSE, better the performance of the fusion algorithm.

Peak Signal to Noise Ratio (PSNR) PSNR is the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. The PSNR of the fusion result is defined as follows:

$$PSNR = 10\times\log\left(\frac{(f_{\max})^2}{RMSE^2}\right) \tag{10}$$

where, f_{max} is the maximum scale value of the pixels in the fused image. Higher the value of the PSNR, better the performance of the fusion algorithm.

Correlation Coefficient (CC) Correlation coefficient is a measure of similarity in small size structures between the original and the fused images. Its value varies from -1 to +1. Values closer to +1 indicates that the fused and source images are highly similar while values closer to -1 indicates the dissimilarity of the fused and source image:

$$CORR = \frac{2C_{rf}}{C_r + C_f} \tag{11}$$

$$C_r = \sum_{i=1}^{M}\sum_{j=1}^{N} I_r(i,j)^2 \quad C_f = \sum_{i=1}^{M}\sum_{j=1}^{N} I_f(i,j)^2$$

$$C_{rf} = \sum_{i=1}^{M}\sum_{j=1}^{N} I_f(i,j) I_r(i,j)$$

where,

C_r = The reference image
C_f = The fused image respectively

(a) (b)

(c)

Fig. 2: Hyperspectral 4D Image of anemone blanda schott and kotsky flower, (a) Anemone flower visible image, (b) Anemone flower UV image and (c) IR image of anemone flower

(a) (b)

(c) (d)

Fig. 3: Visible + UV image fusion, (a) Average method, (b) Laplacian pyramid method, (c) Maximum method and (d) PCA method

EXPERIMENTAL RESULTS AND COMPARISONS

The visible, IR and UV images are taken as the source images. The input images are shown in Fig. 2a, b and c. Initially the fusion operation is performed between the visible and IR images. The fusion results of the visible and an IR images using different fusion methods are shown in the Fig. 3c, d, e and f. Then fusion operation is performed between the visible and UV images. The fusion results using different fusion methods are shown in the Fig. 4g, h, I and j.

(a) (b)

(c) (d)

Fig. 4: Visible +IR image fusion, (a) Average method, (b) Laplacian pyramid method, (c) Maximum method and (d) PCA method

Table 1: Visible and IR image fusion based on MWT

		Parameters			
Fusion rule	Plane	Entropy	RMSE	PSNR	CC
Average method	R-plane	6.9957	6.3907	32.0199	0.9441
	G-plane	6.9164	13.2018	25.7182	0.4030
	B-plane	6.6176	14.1155	25.1369	-0.0325
Maximum method	R-plane	6.8553	1.6271	43.9026	0.8735
	G-plane	6.8751	12.2864	26.3423	0.3136
	B-plane	6.1895	12.0090	26.5407	0.5827
PCA method	R-plane	6.9336	6.3817	32.0168	0.9203
	G-plane	6.9164	13.1280	25.7132	0.3189
	B-plane	6.6147	14.1105	25.1169	-0.0325
Laplacian pyramid method	R-plane	7.1190	9.4640	28.6093	0.9066
	G-plane	6.5745	12.8418	25.9583	0.0148
	B-plane	5.5976	13.8627	25.2939	-0.0275

From Table 1, it is observed that the fusion methods Laplacian pyramid, Average, PCA, Select Maximum methods have higher entropy values. In the case of PSNR, Select Maximum Average methods have higher metric values compared to other fusion methods. Select Maximum, PCA and Average fusion methods have lower RMSE and higher Correlation coefficient values.

From Table 2, considering the entropy value, fusion methods namely Average, PCA and Select maximum have higher values. In the case of RMSE, Select maximum has the lower value compared to all other fusion methods. It is observed that, PSNR value is higher in Select maximum and Average fusion methods. Laplacian pyramid and Average methods have higher Correlation coefficients compared to other methods.

Table 2: Visible and UV image fusion based on MWT

		Parameters			
Fusion rule	Plane	Entropy	RMSE	PSNR	CC
Average method	R-plane	7.0196	31.7569	33.1124	0.8328
	G-plane	6.5214	13.5219	25.5100	-0.2092
	B-plane	6.0995	14.3594	24.9881	-0.1660
Maximum method	R-plane	5.3286	5.6714	53.0659	0.7562
	G-plane	6.8939	12.9913	25.8578	-0.2151
	B-plane	5.9520	14.1602	25.1094	0.2995
PCA method	R-plane	7.0810	5.6353	33.0811	0.7030
	G-plane	6.5134	12.8740	25.4622	-0.2162
	B-plane	4.7127	14.3275	25.0053	-0.1248
Laplacian pyramid method	R-plane	6.0499	10.2074	27.9525.	0.7736
	G-plane	6.6624	13.1723	25.7376	-0.2826
	B-plane	4.5436	14.3275	25.0074	-0.1489

CONCLUSION

We have proposed an improved method for fusing multidimensional color images using the YCbCr color model based on the Multi-Wavelet Transform and the performance of the fusion process is analysed using four different fusion measures. The outputs of different fusion methods prove that there is an improvement in information content of the fused images compared to the source images. Moreover our proposed color image fusion method outperforms the previous methods in terms of both numeric and visual quality of reconstructed images.

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