ISSN (Print) : 2319-5940
ISSN (Online) : 2278-1021

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 2, Issue 7, July 2013

Efficient Image Fusion in Color Images Using Multiresolution Transform Techniques

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Abstract: Image fusion is the process of integration of two or more source images into a single fused image. The resultant fused image is used to retain the important features of the source images. Color image fusion is the process of integrating one or more color images to enhance clarity of the image. The application of color image fusion simplifies object identification and helps in better cognition. In the existing system, image fusion is done on gray scale images by using the hybrid of Nonsubsampled Contourlet Transform (NSCT) and Stationary wavelet transform (SWT) techniques. In the proposed system, image fusion is done on color images by using the hybrid of Curvelet (CT) and Contourlet transform techniques. Curvelet and Contourlet transform techniques are multiscale-multidirectional decomposition techniques. The proposed hybrid technique called Serial Contourlet Aiding Curvelet Transform (SCAC) is applied on color images. From the experiments, it is shown that the proposed technique works better than the single multiresolution techniques in color images.

Keywords: Image fusion, Multiresolution Analysis, NSCT, Curvelet transform.

I. INTRODUCTION

Image fusion can be applied in robot vision, image classification, concealed weapon detection and detection of tumors in medical images. The fusion of images is performed on images acquired from different instrument modalities. In this paper, the images are decomposed using multiresolution transform based techniques and the method of pixel averaging or maximum selection rule is applied for fusion.

The papers [1-2] use DWT transform for image fusion with the help of fusion rules. Li, et al. [3] use the Discrete Wavelet Frame Transform (DWFT) for decomposing the image and then the wavelet coefficients are fused by Support Vector Machine (SVM) algorithm. Beaulieu, et al. [4] propose the pixel level SWT decomposition method to refine a multispectral image. This technique is also used for the non-dyadic images.

Li, et al. [5] applies Fast Discrete wavelet Transform (FDWT) to fuse remotely sensed images. RGB components are converted into IHS components and integrated to obtain the fused coefficients using inverse IHS transform. Chen, et al. [6] uses ridgelet transform for fusion of remotely sensed images. The fused image from different sensors takes the advantage of line features of the source images effectively.

Zhou, et al. [7] extracts geometric information using NSCT. The papers [8-10] perform image fusion using NSCT on various types of images. The hybrid multiresolution techniques are used to improve the overall performance of fusion. Li and Liu [11] apply a hybrid method combining SWT and NSCT for image fusion. Chappelier et al. [12] propose image coding technique based on contourlet and wavelet transform.

Tang and Gzhao [13] perform image fusion using Wavelet Based Contourlet Transform (WBCT) technique. WBCT uses the wavelet transform and the directional filter bank to obtain the decomposed coefficients. Mintianoudis and Stathaki [14] use the optimal decoding technique on the decomposed coefficients of sensor images.

Sun and Xiang et al. [15] perform image fusion of color images using NSCT technique. The decision map is obtained by fusing the high frequency coefficients through the scheme of Synthesis Image Absolute Value Select Maximum (SI-AVSM).

Myungjin and Young et al. [16-17] perform the image fusion using curvelet transform. C.S. Xydeas and V.Petrovic [18] propose the algorithm to measure the quality of the fused image.

The paper is organized as follows. Section II presents the general image fusion structure. Section III deals with multiresolution methods used for the image fusion. Section IV shows the experimental results for the different fusion methods and Section V summarizes the performance evaluation of different fusion methods using suitable performance metrics.

ISSN (Print) : 2319-5940
ISSN (Online) : 2278-1021

International Journal of Advanced Research in Computer and Communication Engineering
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II. PAPER OVERVIEW

The image fusion produces a single image from the set of input images. The fused image should have wholesome information useful for human and machine perception. Image fusion improves reliability (by redundant information) and capability (by complementary information). General block diagram of the image fusion is shown in Fig.1.

At first, the input images (I1…In) are registered. Then the registered input images are decomposed based on multiresolution transformation to obtain corresponding coefficients C1,…..,Cn. The coefficients are integrated based on fusion rule to get the composite and complete information of the two source images. Then the inverse transformation is applied to get the fused coefficients.

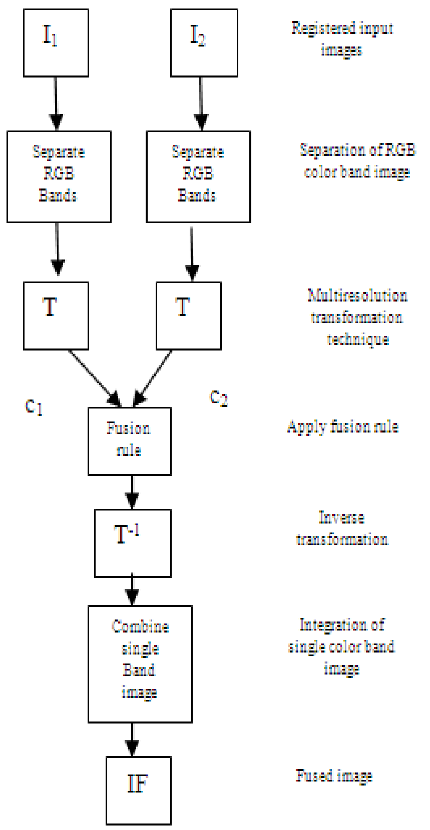

Fig.1. General Structure of color Image Fusion

III.METHODS

A. Single Image Fusion Methods

1. DWT (Discrete Wavelet Transform)

The 2D wavelet transform is applied on source images. After one level of decomposition, there will be four frequency bands namely Low-Low (LL), Low-High (LH), High-Low (HL) and High-High (HH). The next level decomposition is applied to LL band of current decomposition stage. Then N level decomposition will finally have 3N+1 different frequency bands. The steps followed in the DWT based fusion are as follows:

- Register source images.
- Apply DWT transform on the source images.
- Then fuse the decomposed coefficients by calculating the maximum energy and maximum activity level comparison defined below.

$$E^{DWT}(i,j) = \sum_{s=1}^{S}\sum_{d=1}^{D}(DWT(i,j))^2 \qquad (1)$$

$$A^{DWT} = W * E^{DWT} \qquad (2)$$

$$\text{Where,}\quad W = \frac{1}{256}\begin{bmatrix} 4 & 4 & 4 & 4 & 4 \\ 4 & 16 & 16 & 16 & 4 \\ 4 & 16 & 64 & 16 & 4 \\ 4 & 16 & 16 & 16 & 4 \\ 4 & 4 & 4 & 4 & 4 \end{bmatrix}$$

$$F(H1,H2) = \begin{cases} H1(m,n); & if \quad A1(m,n) > A2(m,n) \\ H2(m,n); & if \quad A2(m,n) > A1(m,n) \\ \{H1(m,n) + H2(m,n)\}/2; & Otherwise \end{cases} \qquad (3)$$

- Apply the inverse DWT transform

2. Stationary Wavelet Transform (SWT)

The SWT is the translation invariant DWT transform. The SWT decomposes the 2D image into four subband structures as A, V, H, D namely Approximate, Vertical, Horizontal and Diagonal. The approximate subband is used for next level of the decomposition. The fusion process is similar to DWT. Instead of DWT, here SWT transform is applied.

3. NonSubsampled Contourlet Transform (NSCT)

The NSCT is a multiscale and multidirectional filter bank. NSCT is a new extension of the wavelet transform in two dimensions. It can effectively capture the image edges along the dimension contour. Contourlet framework is a combination of laplacian pyramid and the directional filter band. Laplacian pyramid is used to capture high coefficients. The contourlet transform produces coefficients in 2^{l_j} direction, where l_j represents the directional information. It uses the parameter 'nlevel' for

ISSN (Print) : 2319-5940
ISSN (Online) : 2278-1021

International Journal of Advanced Research in Computer and Communication Engineering
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number of levels of decomposition. If the decomposition level is 0, then it uses the wavelet transform. Otherwise the image is subdivided into 2^{l_j} directions. The length of the image is equal to nlevels+1. The coefficients y[0,1,..,n] are obtained out of NSCT decomposition. The y[0] coefficient is the low level coefficient while the remaining y[1,2,…,n] are the high level coefficients. The contourlet transformation framework is shown in Fig.2.

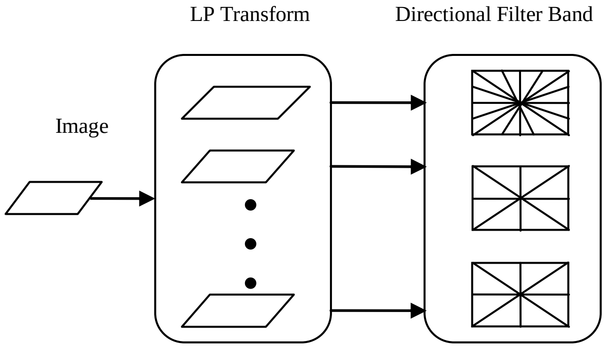

Fig.2. Contourlet Framework

The NSCT transformation is applied on the source images. Then activity level comparisons are performed on each pixel of the source mages lying in the same position to select the maximum energy pixel. The fused image is reconstructed by performing inverse transform.

4. Curvelet Transform (CT)

Curvelet transform is also a multiresolution decomposition technique. The 2D-FFT (Two dimensional Fast Fourier Transform) is applied on images to obtain the Fourier samples. The Fourier samples are wrapped around the origin. Finally the image is reconstructed by performing the inverse FFT transform.

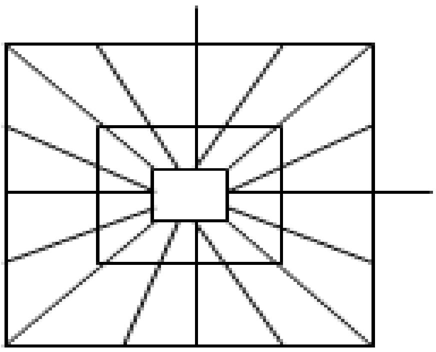

Fig. 3 Curvelet Transform

B. Hybrid Image Fusion Techniques

1. Serial DWT Aiding NSCT (SDAN)

The source images are decomposed into low and high coefficients using the NSCT transform. The low coefficients are fused using DWT transform by using the fusion rule activity level comparisons. Finally the inverse NSCT transform is applied to the fused low and high coefficients to get the fused image.

2. Serial SWT Aiding NSCT (SSAN)

The source images are decomposed into low and high coefficients by applying NSCT Transform. The decomposed low coefficients are fused by using SWT transform following the same procedure. Finally fused low and high coefficients are integrated into a single image by applying inverse NSCT transform.

3. Serial NSCT Aiding Curvelet (SCAC)

The source images are first decomposed using Curvelet Transform and the low coefficients of the curvelet transform are decomposed using contourlet transform.

4. Serial SWT Aiding Curvelet (SSAC)

The source images are decomposed using SWT and the low coefficients are further decomposed into low and high coefficients.

IV. EXPERIMENTS

A. Experimental Data

Twin clock images of the same size (192x256) are downloaded from the websource [19]. The images are shown in Fig 3(a) and Fig 3(b). In Fig 3(a), the right clock is focused and in Fig 3(b), left clock is focused.

B.Experiment 1-DWT

DWT transform is applied on the two source images. When the DWT transform is applied at the first level, the 512x512 image pixels are equally divided into 128x128 pixels for each frequency subband. The LL subband is used for further level of decomposition. Final fused image is obtained by performing inverse transform. The resultant fused image in Fig 3(c) obviously has better focus and clarity than the source images before fusion.

C. Experiment 2-SWT

The SWT transform is applied on the source images. The rest of the procedure for fusion is similar to the procedure explained in *Experiment 1*. The resultant fused image using SWT is shown in Fig 3(d) and it has better accuracy and clarity than the fused image obtained using DWT transform.

D.Experiment 3-NSCT

NSCT transform is applied on the source images during which the 512x512 sized images is divided into 256x256 sized low coefficient and the remaining pixels into high coefficients based on the decomposition level. Here NSCT

ISSN (Print) : 2319-5940
ISSN (Online) : 2278-1021

International Journal of Advanced Research in Computer and Communication Engineering
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transformation is performed in first and second levels. The fused image is obtained by performing inverse NSCT transform. The fused image in Fig 3(e) better clarity and is more accurate than the fused images got from DWT and SWT based techniques.

E. Experiment 4-Curvet Transform

Curvelet transform is applied on the two source images. The decomposition is done at level 2. Then the source images are decomposed into one low coefficient image and 8 high coefficient images. The resultant image is shown in Fig 3(f).

F.Experiment 5-SDAN

This method is a hybrid multiresolution technique. Here the NSCT transform is applied to the source images. The low coefficients of each source image are fused by performing DWT transform. Then the fused low and high coefficients are used to obtain the final fused image by using the inverse NSCT transform. The resultant image in Fig 3(g) and it highlights all subtle informations completely than the fused images obtained from single multiresolution methods.

G.Experiment 6-SSAN

This method is a combination of NSCT and SWT techniques. After performing NSCT transform, the low coefficients of the NSCT transform are fused by applying SWT transform. The resultant fused image in Fig 3(h) gives commendable results.

H. Experiment 7-SCAC

This method uses the combination Curvelet and Contourlet transform techniques and is proposed in this paper. The resultant image using this technique is shown in Fig 3(i).

I. Experiment 8-SSAC

This method uses the combination of Curvelet transform and the contourlet transform. The resultant image obtained is shown in Fig 3(j).

J. Experiment 9-SCAN

This method combines two techniques such as NSCT and Curvelet transforms. Images are decomposed using Contourlet transform then fused using curvelet transform.

Fig. 4. (a) Source Image-1 ; (b) Source Image-2; (c) DWT fused image; (d) SWT fused image; (e) NSCT fused image; f) curvelet fused image (g) SDAN fused image; (h) SSAN fused image (i) SCAC fused image (j) SSAC Fused image.

K. Results

V. PERFORMANCE EVALUATION

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Performance of the fused images obtained using various techniques is evaluated based on performance metrics such as RMSE (Root Mean Square Error), PSNR (Peak signal to Noise Ratio), $Q^{AB/F}$ [15] that are explained in this section.

A. RMSE

The RMSE is a measure of accuracy commonly used as a reference based assessment metric and is defined as follows:

$$RMSE = \frac{1}{mn}\sum_{i=0}^{m-1}\sum_{j=0}^{n-1}[R(i,j) - F(i,j)]^2 \quad (4)$$

Where R(i,j) is the reference image F(i,j) is the fused image and m,n are the image dimensions. A good fusion method should have minimal error.

B. PSNR

This measure is commonly used as a measure of quality of an image. It is defined from the root mean square error (RMSE) as follows:

$$PSNR = 10.\log_{10}(MAX_I^2 / RMSE) \quad (5)$$

Where MAX_I represents the maximum possible pixel values of the image. A good fusion method should have maximal PSNR value.

D. $Q^{AB/F}$

This measure is used to evaluate the amount of edge information transferred from input images to the fused image. Consider two input images A and B and let the resulting fused image be F. Then $Q^{AB/F}$, a normalized performance metric for NxM sized image will be defined as follows:

$$Q^{AB/F} = \frac{\sum_{n=1}^{N}\sum_{m=1}^{M} Q^{AF}(n,m)w^A(n,m) + Q^{BF}(n,m)w^B(n,m)}{\sum_{i=1}^{N}\sum_{j=1}^{M}(w^A(i,j) + w^B(i,j))} \quad (6)$$

Where $Q^{AF}(n,m)$, $Q^{BF}(n,m)$ are the edge information preservative values at location (n,m) and $w^A(n,m)$, $w^B(n,m)$ are the weights assigned to edge information. A good fusion method should have maximal $Q^{AB/F}$ value.

E. Information entropy

Information entropy is a measure of the source images and is defined as follows.

$$H(X) = -\sum_{i=0}^{A-1} p_i \log_2(p_i) \quad (7)$$

Where P is the probability of the pixels with gray level i and A stands for the image gray series.

TABLE 1
Performance Measures of Color Images

Method	Multiresolution Transformation Technique	Performance Metrics			
		RMSE	PSNR	QABF	Entropy
Single Multi Resolution methods	DWT	7.7490	34.9370	0.0013	0.0200
	SWT	6.9376	36.0430	0.0014	0.0675
	NSCT	6.3142	36.9846	0.0014	0.3585
	CURVELET	6.0883	37.3489	0.0015	0.0202
Hybrid multi resolution methods	SDAN	6.2759	37.0454	0.0015	0.1120
	SSAN	6.0883	37.3489	0.0015	0.2178
	SCAC	6.0012	37.4931	0.0017	0.4168
	SSAN	6.020	37.4618	0.0016	0.2178
	SCAN	6.0883	37.3439	0.0015	0.3219

Table1 shows RMSE, PSNR, $Q^{AB/F}$ and Information Entropy values obtained from the experiments. The performance metrics are plotted in the graph shown in Fig 5.

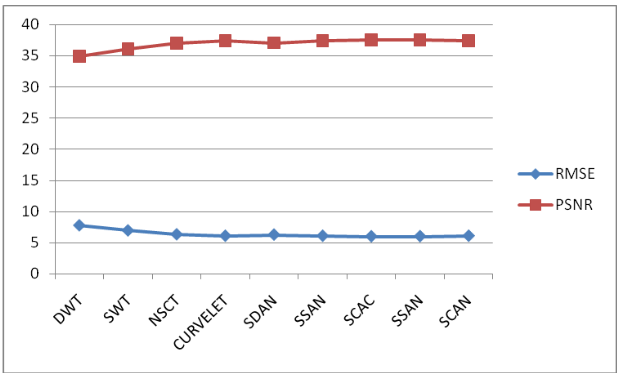

Fig 5(a) Performance graph RMSE and PSNR metrics

For SCAC the minimal RMSE value of 6.0012 is obtained while the PSNR and $Q^{AB/F}$ values obtained are 37.4931 and 0.0017. Next to SCAC the hybrid combination of SSAN and SCAN gave the better results for the same images.

VI. CONCLUSION

In this work, single and hybrid multiresolution methods are applied with novelty to integrate the color images of the same scene taken at different times. The color image fusion process uses different multiresolution

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ISSN (Online) : 2278-1021

International Journal of Advanced Research in Computer and Communication Engineering
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methods to explore the complementary characteristics of two images. From the experiments, it is evident that hybrid methods work better than the single multiresolution methods. A new hybrid multiresolution technique is proposed in this paper which is the combination of curvelet transform and contourlet transform (SCAC). The proposed serial hybrid method works better than the single multiresolution methods and other hybrid methods implemented in this paper.

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BIOGRAPHY

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