Survey on Different Image Fusion Techniques

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Abstract- The term fusion means in general an approach to extraction of information acquired in several domains. The objective of Image fusion is to combine information from multiple images of the same scene in to a single image retaining the important and required features from each of the original image. The main task of image fusion is integrating complementry information from multiple images in to single image. The resultant fused image will be more informative and complete than any of the input image and is more suitable for human visual and machine perception. Certain algorithms can perform image fusion process. Image fusion techniques can improve the quality and increase the application of this image. The purpose of this paper to present an overview on different techniques of image fusion, such as primitive based fusion (averaging method, select maximum, select minimum), discrete wavelet transform based fusion, principal component analysis based fusion etc [1].

Keywords: Image Fusion, Fusion Methods, Discrete wavelet Transform (DWT), Root mean square error (RMSE), Peak signal to noise ratio (PSNR), Principal Component Analysis (PCA).

I. INTRODUCTION

Image fusion is the process that combines information from multiple images of the same scene. The object of the image fusion is to retain the most desirable characteristics of each image. Thus the new image contains a more accurate description of the scene than any of the individual image and is more suitable for human visual and machine perception. It also reduces the storage cost by storing just the single fused image instead of multiple images. For medical image fusion, the fusion of image provides additional clinical information, which is otherwise not apparent in the separate images. However, the instruments are not capable of providing such information either by design or because of observational constraints, one possible solution for this is image fusion. The image fusion techniques are used in navigation guidance, object detection and recognition, medical diagnosis (like CT, MRI, MRA, PET) [1], [2], satellite imaging for remote sensing, computer vision and robotics, military and civilian surveillance etc.

II. IMAGE FUSION ALGORITHMS

Any image fusion algorithm must satisfy two main requirements.
First- they must identify the most significant features in the input images and transfer them without loss of detail into the fused image.
Second- the fusion method should not bring in any inconsistencies or artifacts, which would distract the human observer [4].
Image fusion method can be broadly classified into two groups;

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1) SPATIAL DOMAIN BASED FUSION METHOD

In spatial domain techniques, we directly deal with the image pixels. The pixel values are manipulated to achieve desired result.

Spatial domain based method-it has following method

A) Intensity-hue-saturation transform based fusion
B) Principal component analysis based fusion
C) Averaging method
D) Select maximum
E) Select minimum

A) INTENSITY-HUE SATURATION TRANSFORMED BASED FUSION

Hue (H) refers to the average wavelength of the light contributing to the colour, Intensity (I) the total brightness of the color and saturation (S) the purity of the color. The HIS transform fusion isolate spatial (I) and spectral (H, S) data from RGB images [10].This belongs to color image fusion algorithms.
Mathematically, the transformation from the standard RGB colour scheme to the IHS scheme is given by:

$$\begin{bmatrix} I \\ V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{3}} \\ \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{6}} & -\frac{2}{\sqrt{6}} \\ \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} & 0 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (1)$$

Where, $H = \tan^{-1}(V_2/V_1)$ $S = \sqrt{V_1^2 + V_2^2}$
I= (R+G+B)/3
V_1 & V_2 are intermediate variables.
The reverse transformation is given by:

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{6}} & \frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{6}} & -\frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{3}} & -\frac{2}{\sqrt{6}} & 0 \end{bmatrix} = \begin{bmatrix} I \\ V_1 \\ V_2 \end{bmatrix} \quad (2)$$

B) PRINCIPAL COMPONENT ANALYSIS BASED FUSION

Principal component analysis is a mathematical tool frequently used for reducing dimensions of image that have not been separated into classes. Suppose we have a set of 2-dimensional image whose x-coordinates and y-coordinates are given below:
$X=\{x_1, x_2, x_3, x_4, x_5, x_6\}$
$Y= \{y_1, y_2, y_3, y_4, y_5, y_6\}$
The original data set D is represented like $D= [X^T, Y^T]$

Step1 Calculate mean of the data points, µX, µY.

Step2 Subtract the mean from each data point to generate normalized data set, nX=X- µX, nY =Y- µY, thus we get $nD= [nX^T, nY^T]$.

Step3 Calculate Covariance matrix C of the normalizes data set. Covariance is measure of how much each of the dimensions varies from the mean with respect to each other, i.e.

$$\operatorname{cov}(X,Y) = \frac{1}{(n-1)} \sum_{i=0}^{n} (X_i - \mu X)(Y_i - \mu Y)$$

Covariance matrix is given by;

$$C = \begin{bmatrix} \operatorname{cov}(nX, nX) & \operatorname{cov}(nX, nY) \\ \operatorname{cov}(nY, nX) & \operatorname{cov}(nY, nY) \end{bmatrix}$$

Step4 Calculate Eigenvectors and Eigen values of the covariance matrix C. i.e.

$|C - \lambda I| = 0$ For eigenvalue
.
And for eigenvector $(C-\lambda_i I).V_i$ I = no. of eigenvalue.
V_i is the eigenvector.

Step5 Generate principal component axis

The eigenvector with the highest eigenvalue is the principal component of the data set. It physically represents the axis of projection for best discrimination. Plotting with these highest eigenvector corresponding highest eigenvalue against nX generates the axis.

Step6 Represent normalized data points in eigenspace

The normalized data points are transformed so that they can be represented the eigenspace. The eigenspace is formed by the two eigenvectors as coordinate axes. The data points are mapped to this space by projecting them onto the two eigenvectors, which constitute the final data representation.
i.e. $F_i=V_i^T.nD^T$, i=no. of eigenvalue

Step7 Dimensionality reduction

The reduction in dimensionality is achieved by projecting the transformed data points in eigenspace on to the principal component axis.

C) AVERAGE METHOD

In this method the resultant fused image is obtained by taking the average intensity of corresponding pixels from both the input image.
F (x, y) = (A (x, y) +B (x, y))/2
Where A (x, y), B (x, y) are input image and F (x, y) is fused image. And point (x, y) is the pixel value.

For weighted average method-

$$F(x,y) = \sum_{x=0}^{m} \sum_{y=0}^{n} (WA(x,y) + (1-W)B(x,y))$$

Where W is weight factor and point (x, y) is the pixel value.

D) SELECT MAXIMUM

In this method, the resultant fused image is obtained by selecting the maximum intensity of corresponding pixels from both the input image.

$$F(x,y) = \sum_{x=0}^{m} \sum_{y=0}^{n} Max(A(x,y) + B(x,y))$$

Where A (x, y), B (x, y) are input image and F (x, y) is fused image, and point (x, y) is the pixel value.

E) SELECT MINIMUM

In this method, the resultant fused image is obtained by selecting the minimum intensity of corresponding pixels from both the input image

$$F(x,y) = \sum_{x=0}^{m} \sum_{y=0}^{n} Min((A(x,y) + B(x,y))$$

Where A (x, y), B (x, y) are input image and F (x, y) is fused image, and point (x, y) is the pixel value.

2) FREQUENCY TRANSFORMS DOMAIN FUSION

In frequency domain methods the image is first transferred in to frequency domain. It means that the Fourier Transform of the image is computed first. All the Fusion operations are performed on the Fourier transform of the image and then the Inverse Fourier transform is performed to get the resultant image.

Frequency domain –it has the following method

A) Pyramid Decomposition Based Fusion
i. Laplacian pyramid
ii. Gradient pyramid
iii. Morphological pyramid
IV. Ratio of low pass pyramid
V. filter-subtract-decimate method

B) Discrete wavelet transform based fusion

A) PYRAMID DECOMPOSITION BASED FUSION

A pyramid decomposition fusion consists of a number of images at different scales which together represent the original image. In general, every pyramid transform consists of three major processes:

1) Decomposition

Decomposition is the process where a pyramid is generated in succession at each level of the fusion. The depth of the fusion or number of levels of fusion is predefined.

The input images are first passed through a low pass filter, the images are filtered. After that the pyramid is generated from the filtered images. The input images are then decimated to half their size, which would act as the input image matrices for the next level of decomposition.

2) Formation of the initial image for re-composition

The input images are merged after the decomposition process. This resultant image would be used as the initial Input to the re-composition process. The finally decimated input images are worked upon either by averaging the decimated input images, selecting the minimum decimated input image or selecting the maximum decimated input image.

3) Re-composition

In the re-composition process, the resultant image is finally created from the pyramids formed at each level of decomposition.

i. LAPLACIAN PYRAMID

The Laplacian Pyramid implements a "pattern selective" approach to image fusion, so that the composite image is constructed not a pixel at a time, but a feature at a time.
The first step is to construct a pyramid for each source image; the fusion is then implemented for each level of the pyramid using feature selection decision. There are two modes of the combination averaging and the selection. In the selection process the most salient component pattern from the source image are copied while less salient patterns are discarded. In the averaging case source patterns are averaged reducing the noise. Selection is used where the source images are distinctly different and the averaging is used where the source images are similar [7].

ii. GRADIENT PYRAMID

A gradient pyramid of an image is obtained by applying gradient operators to the Gaussian pyramid at each level. The gradient operators are used in the horizontal, vertical, and 2 diagonal directions. At each level, these 4 directional gradient pyramids are combined together to obtain a combined gradient pyramid.

iii. MORPHOLOGICAL PYRAMID

Applying morphological filters to the Gaussian pyramid at each level and taking the difference between 2 neighboring levels generate a morphological pyramid. A morphological filer is generally used for image smoothing.

iv. RATIO OF LOW PASS PYRAMID

Ratio of Low Pass Pyramid is another method in which at every level of the image, the ratio of two successive level is taken.

v. FILTER-SUBTRACT-DECIMATE METHOD

The filter-subtract-decimate pyramid fusion method is conceptually the same as the Laplacian pyramid fusion method. The sole difference is in the stage of obtaining the difference images during the creation of the pyramid.

B) DISCRETE WAVELET TRANSFORM BASED METHOD

Wavelets were first introduced in seismology to provide a time dimension to seismic analysis that Fourier analysis lacked. Fourier analysis is ideal for studying stationary data (data whose statistical properties are invariant over time) but is not well suited for studying data with transient events that cannot be statistically predicted from the data's past. Wavelets were designed with such non-stationary data.

"Wavelet transforms allow time – frequency localization"

Wavelet means "small wave" so wavelet analysis is about analyzing signal with short duration finite energy functions.
They transform the signal under investigation in to another representation, which presents the signal in a more useful form. Mathematically, we denote a wavelet as;

$$\psi_{a,b}(t) = \frac{1}{\sqrt{|a|}}\psi((t-b)/a) \qquad (3)$$

Where b=is location parameter
a=is scaling parameter

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for a given scaling parameter a, we translate the wavelet by varying the parameter b. we define the wavelet transform as:

$$w(a,b) = \int_t f(t) \frac{1}{\sqrt{|a|}} \psi((t-b)/a) \quad (4)$$

According equation (4), for every (a, b), we have a wavelet transform co-efficient, representing how much the scaled wavelet is similar to the function at location, t = b/a.

"If scale and position is varied very smoothly, then transform is called continuous wavelet transform."

"If scale and position are changed in discrete steps, the transform is called discrete wavelet transform."

For a 2D M×N image array A the 2D DWT is given by equation-

$$W_N.A.W_N^T = \begin{pmatrix} B & V \\ H & D \end{pmatrix} \quad (5)$$

Here, B is called the approximation or blur matrix and represents the average of the elements of A. Suppose A is the 4×4 matrix

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} \quad (6)$$

Then B is given by

$$B = \frac{1}{4} \begin{bmatrix} (a_{11}+a_{12}+a_{21}+a_{22}) & (a_{13}+a_{14}+a_{23}+a_{24}) \\ (a_{31}+a_{32}+a_{41}+a_{42}) & (a_{33}+a_{34}+a_{43}+a_{44}) \end{bmatrix} \quad (7)$$

V is called the vertical difference matrix and it is given by

$$V = \frac{1}{4} \begin{bmatrix} (a_{11}+a_{21})-(a_{12}+a_{22}) & (a_{13}+a_{23})-(a_{14}+a_{24}) \\ (a_{31}+a_{41})-(a_{32}+a_{42}) & (a_{33}+a_{43})-(a_{34}+a_{44}) \end{bmatrix}$$

(8)

H is called the horizontal difference matrix and is given by

$$H = \frac{1}{4} \begin{bmatrix} (a_{11}+a_{12})-(a_{21}+a_{22}) & (a_{13}+a_{14})-(a_{23}+a_{24}) \\ (a_{31}+a_{32})-(a_{41}+a_{42}) & (a_{33}+a_{34})-(a_{43}+a_{44}) \end{bmatrix}$$

(9)

D is called the diagonal difference matrix and is given by

$$D = \frac{1}{4} \begin{bmatrix} (a_{11}+a_{22})-(a_{12}+a_{21}) & (a_{13}+a_{24})-(a_{23}+a_{14}) \\ (a_{31}+a_{42})-(a_{32}+a_{41}) & (a_{33}+a_{44})-(a_{43}+a_{34}) \end{bmatrix}$$

(10)

So by using these values the discrete wavelet transformed is calculated in multiple lavel.

A wavelet transform is applied to the image resulting in a four-component image: a low-resolution approximation component (LL) and three images of horizontal (HL), vertical (LH), and diagonal (HH) wavelet coefficients which contain information of local spatial detail. A selected band of the multispectral image then replaces the low-resolution component. This process is repeated for each band until all bands are transformed. A reverse wavelet transform is applied to the fused components to create the fused multispectral image. Image fusion method is shown in following fig (1) [3];

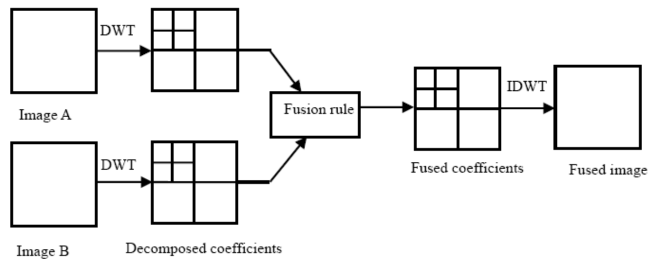

Fig.1. the image fusion scheme using the wavelet transforms.

III. COMPARATIVE STUDY OF VARIOUS IMAGE FUSION TECHNIQUES

On the basis of the study only few comparisons between the different existing fusion techniques have been made and are analyzed theoretically which are shown in Table 1 as below.[2]

Table-1

Sl n.	Fusion technique/ algorithm	domain	advantage	disadvantage
1	Simple average	Spatial	This is the simplest method of image fusion.	The main disadvantage of this method is that it does not give guarantee to have a clear object from the set of image.
2	Simple maximum	Spatial	In simple maximum method highly focused image output obtained from the input image	This method is affected by blurring effect, which directly affects the contrast of the image.
3	Principal component analysis method	Spatial	Principal component analysis is a tool, which transforms number of correlated variable in to number of uncorrelated variables; this property can be used in image	This method produce spectral degradation

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			fusion.	
4	Discrete wavelet transform method	Trans-form	It is minimizing the spectral distortion. It provide better signal to noise ratio than pixel-based method.	In this method final fused image have a less spatial resolution.

IV EXPERIMENTAL RESULTS

Let P (i, j) is the original image, F (i, j) is the fused image, (i, j) is the pixel row and column index and M and N are the dimension of the image. The smaller the value of RMSE, the better the fusion performance. [3].

1) The root mean square error (RMSE) is given by:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{M}\sum_{j=1}^{N}[P(i,j)-F(i,j)]^2}{M\times N}} \qquad (11)$$

Now we define the peak signal to noise ratio (PSNR)

$$PSNR = 10\times\log_{10}\left((f_{\max})^2 \big/ RMSE^2 \right) \qquad (12)$$

Where f_{max} is the maximum gray scale value of the pixels in the fused image. The higher the value of the PSNR, the better the fusion performance.

Fig.2. Pair of Input Images

(a) (b)

(c) (d)

Fig.3. Fused images using different algorithms ((a)-(e) are fused images, the methods used from (a) to (e) are: Average, Maximum, Minimum, PCA, and DWT. [16]

Table -2

Method	RMSE	PSNR
Minimum	92.254	28.4809
Average	42.95	31.800
PCA	0.0232	46.194
Maximum	112.543	26.982
DWT	.0017	75.894

Table -3

Rank based on quality	Rank based on visual quality
DWT	DWT
PCA	PCA
Maximum	Average
Average	Maximum
Minimum	Minimum

V. CONCLUSION

This paper performs the survey on different Image fusion techniques Here, various techniques of Image Fusion that are useful in image fusion is to create a single enhanced image, these fused image is more suitable for human visual and machine perception. This paper presents that which approach is better among all the existing image fusion techniques. Although selection of fusion algorithm is problem dependent but this review results that spatial domain provide high spatial resolution but spatial domain have image-blurring problem. The wavelet transform is the very good technique for the image fusion. It has better value of PSNR when compared to other fusion methods. It shows it is the better fusion technique and it also provides a very high quality spectral content.

REFERENCES

[1] Yong Yang, Dong Sun Park, and Shuying Huang, "Medical Image Fusion via an Effective Wavelet based Approach".

[2] Bedi S. S., Khandelwal Rati, "Comprehensive and Comparative Study of Image Fusion Techniques" International Journal of Soft Computing and Engineering (IJSCE) ISSN: 2231-2307, Volume-3, Issue-1, March 2013.

[3] Ali F. E., Dokany I. M. El, Saad A. A., and Samie F. E. Abd El, "Fusion of MR and CT Images Using The Curvelet Transform" 25th national radio science conference (nrsc 2008) March 18-20, 2008, Faculty of Engineering, Tanta Univ., Egypt.

[4] Kulkarni S., jyoti, "Wavelet Transform Applications" IEEE 978-1-4244-8679-3/11/2011

[5] Sekhar Soma A., Prasad Giri M.N., "A Novel Approach of Image Fusion on MR and CT Images Using Wavelet Transforms" IEEE 2011

[6] Zhang Y., "Understanding image fusion," Photogramm. Eng. Remote Sens., vol. 70, no. 6, pp. 657–661, Jun. 2004.

[7] Krista Amolins, Yun Zhang, and Peter Dare, "Wavelet based image fusion techniques—an introduction, review and comparison", ISPRS Journal of Photogrammetric and Remote Sensing, Vol. 62, pp. 249-263, 2007

[8] H. Li, Manjunath B.S. and Mitra S.K., 1995. "Multisensor image fusion using the wavelet transforms", Graphical Models and Image Processing, 57:234–245.

[9] Jan Flusser, Filip Sroubek, and Barbara Zitov´a, "Image Fusion: Principles, Methods, and Applications" Tutorial EUSIPCO 2007

[10] Kekre H.B., Mishra Dhirendra, Saboo Rakhee, "Review on image fusion techniques and performance evaluation parameters" International Journal of Engineering Science and Technology (IJEST) ISSN: 0975-5462 Vol. 5 No.04 April 2013

[11] Rani K., Sharma R., "Study of Different Image fusion Algorithm" International Journal of Emerging Technology and Advanced Engineering (ISSN 2250-2459, ISO 9001:2008 Certified Journal, Volume 3, Issue 5, May 2013).

[12] Shih–Gu Huang, "Wavelet for Image Fusion".

[13] Y. Zhang, "Understanding image fusion," Photogramm. Eng. Remote Sens., vol. 70, no. 6, pp. 657–661, Jun. 2004
.
[14] Amolins Krista, Yun Zhang, and Peter Dare, "Wavelet based image fusion techniques—an introduction, review and comparison", ISPRS Journal of Photogrammetric and Remote Sensing, Vol. 62, pp. 249-263, 2007.

[15] Zhiming Cui, Guangming Zhang, Jian Wu, "Medical Image Fusion Based on Wavelet Transform and Independent Component Analysis" 2009 International Joint Conference on Artificial Intelligence.

[16] Sruthy S, Latha Parameswaran Ajeesh P Sasi, "Image Fusion Technique using DT-CWT" IEEE 978-1-4673-5090-7/13/2013.