Review Article

A Review and Comparison of Spatial and Transform Domain Image Fusion Techniques

Gurjot Kaur[1], Umesh Sehgal[2]

Abstract

Image fusion is procedure of combination of the numerous images into particular image which comprise improved depiction of the sight and provides enhanced quality of fused image than source images. Image fusion provides a superior significance in defence, military affairs, civilian sector and medical area. This review article delivers a literature evaluation on the image fusion methods such as simple average, select minimum and maximum, principle component analysis, discrete wavelet transform, discrete cosine transform, lift wavelet transform etc. Execution of image fusion techniques can be calculated by parameters like Peak Signal to Noise Ratio, root mean square error, entropy, standard deviation, spatial frequency and mutual information. This article also presents the comparison of all the techniques.

Keywords: Comparison, Image fusion, Quality evaluation measures, Transform and spatial techniques

Introduction

Image fusion is a substantial area in image and signal processing. Image fusion is a procedure of extracting useful information from source images to reduce volume of data and create a composite and fused image.[1] The foremost objective of Image fusion is to compose the fused image suitable not only for human graphical system but also for further image processing errands like image augmentation and de-noising, breakdown, compression, feature recognition, classification and object recognition.[2] Image fusion has many applications in remote or satellite area for proper view of satellite vision. It is also used in medical area for analysis of diseases through imaging vision. Image fusion is used in military areas to detect the threats. It has so many applications in area of human vision, robotics and neural networks also. The three main levels have been deal in literature of image fusion- pixel level, feature level, decision level. Pixel-level could be the mixture of natural knowledge from numerous images into single image. Feature-level perform the operations on features extracted from source images. Decision-level mix the outcomes from numerous methods to provide the final merged image.

When we capture the image with digital or conventional camera then a single image cannot focus on all objects together therefore image fusion method is used to make all in focus image. Figure 1 shows right blurred image and Fig. 2 shows left blurred image. Figure 3 shows the final focused image which contains more information than source images.

[1]Research Scholar, [2]Assistant Professor, Faculty of Computational Science, GNA University, Punjab, India.

Correspondence: Ms. Gurjot Kaur**,** GNA University, Punjab, India.

E-mail Id: kaur.gurjot93@gmail.com

Orcid Id: http://orcid.org/0000-0003-4959-5933

How to cite this article: Kaur G, Sehgal U. A Review and Comparison of Spatial and Transform Domain Image Fusion Techniques. *J Adv Res Embed Sys* 2017; 4(1&2): 1-8.

ISSN: 2395-3802

Figure 1.Right Blurred Image

Figure 2.Left Blurred Image

Figure 3.Composite or Fused Image

Image Fusion Domains

Image fusion technique contains following domains:

Spatial Domain

In Spatial field method we simply deal with pixels and mold the pixels to get fused resultant image. While pixel image fusion methods repeatedly guide to non-existence of spectral information and introduce spatial alterations. It includes many algorithms like Simple average, select maximum, select minimum, PCA etc.

Transform Domain

In transform domain method images are decomposed into multiple scales and transform coefficients are merged together according to specific fusion rules. Finally, the fused image is constructed with inverse transform of the fused coefficients. In this domain algorithms based on wavelet approaches are very successful. It includes many algorithms like DWT, SWT, DCT, LWT etc. In comparison of DWT, DCT, DFCT algorithms LWT is better because of its high speed of computation, energy consumption and high fused quality.

Related Work

Li M et al. proposed image fusion method related to spatial domain.[1] Pixel level image fusion method is used to extract the information and grouping of data coming from registered images and make a relevant composite and fused image. This method deals with pixels only. This article gives review of all substantial image datasets. This image fusion method has many applications in different areas such as in machine vision,

remote sensing, aerospace, remote sensing and medical area etc. But this method has some irregularities.

Wang J et al. approved the PCA based image fusion which expands the determination of the images. In this first decays the image into the sub images and then accomplishes the information fusion and as a final point the resultant image is formed from sub images.[3] Palm-print recognition is performed by using PCA. Liu L et al. have proposed the wavelet based method for multi-focus images. In this first decomposition is performed on images.[5] Images are splits into different frequency bands and after that each level is further decompose to get high fused quality. This technique is fast, simple to implement and use less amount of memory. It is best for human visual system but some artefacts are contained in this method like noise and edge irregularities.

Cao L et al. suggested a method which is DCT based to get high quality composite image.[6] This method shows improved results than other DCT methods. In this technique Joint photographic expert (JPEG) norm are used to access the combinative execution of images. It provides productive calculations for multi-focus images.

Garg R et al. considers that the simple averaging technique illustrations the ruined performance, using wavelet ringing tones are prohibited with sift invariant property.[7] It has been found that the fusion using wavelet demonstrates the superior outcome in most circumstances and in other cases the principal component analysis shows the superior result.

Liu L et al. discovered the pixel based method that is used the multi-resolution decomposition.[5] This method use the source images for further breakdown into wavelets ad curvlet transform. In this technique they calculate the fused pixel value; weight average of the source pixels is occupied, where the weight to be given to pixel is adaptively decided by establishing parent child relationship among pixels at different levels of multi -resolution. In the end ultimate image is compared on the basis of different quality measures to show the better quality of image. This method is tested on several types of multi-focus images. This technique is used for elimination of noise and artefacts.

Image Fusion Techniques

Image Fusion is divided into two domains. Spatial domain is related to pixels and transform domain is based on frequency. Theses domains further include many algorithms to get high quality fused image and other required resources.

Spatial Domain Techniques

- Select Maximum and Minimum Method
- Principle Component Analysis

Select Maximum and Minimum Method

Basically average method is simple technique in which all relevant objects are in focus. In this value of every pixel for image is taken and then obtained result is divided by number 2. Mean value is allocated to every equivalent pixel.

But in select maximum and minimum method selects the focused region from the source images by obtaining the highest value for each pixel and hence results the focused output. Quality of focused image is based on pixel value. Image will be highly focused if pixel value will be higher Pixel value of every image is compared with each other and the highest value is allocated to pixel.

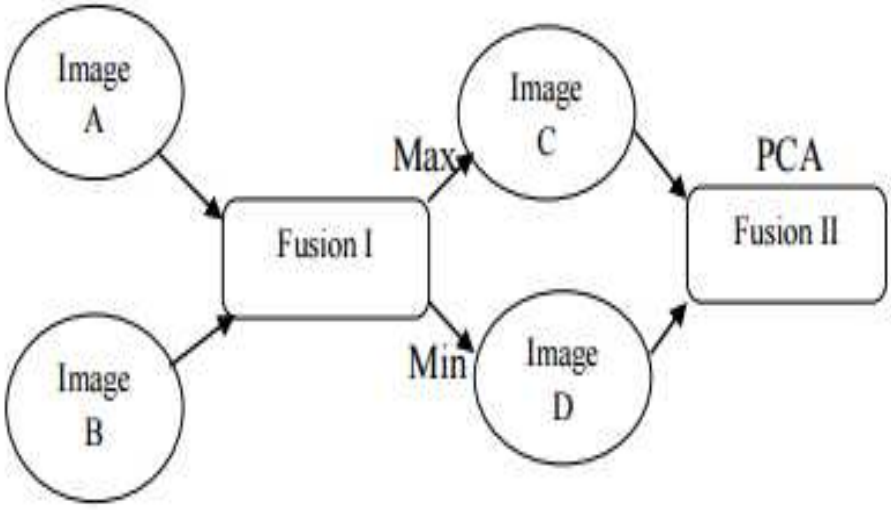

Figure 4.Image Fusion by Applying Max/Min Method

ISSN: 2395-3802

I1 and I2 are source images and if fused output image is given by:

If (x,y) = max (I1 (x,y), I2 (x,y)) Or If (x,y) = min (I1 (x,y), I2 (x,y))

Principle Component Analysis

Principle component analysis technique is statistical technique. It transforms group of related variables into group of original variables. Its main aim is to compress the multiband image information into an image. PCA is a modest true eigenvector based multivariance analysis type. It contains different methods for identifying and to show data patterns, in such a way by means of highpoint their resemblances and alterations, and thus reduce dimensions without loss of data.[3]

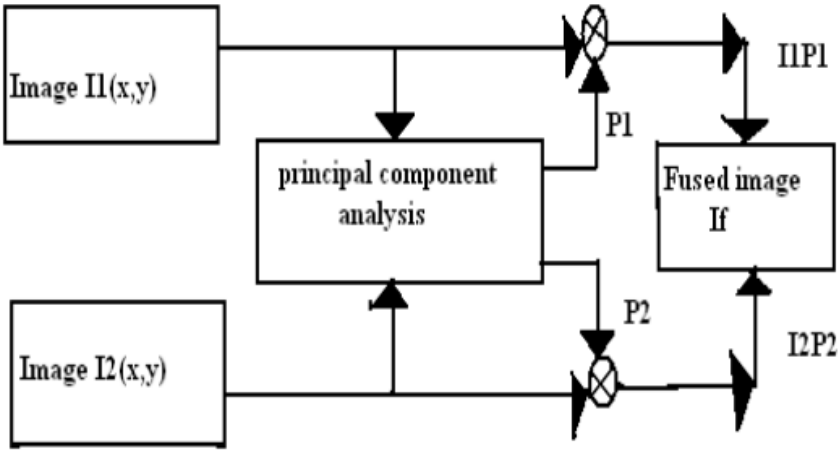

Figure 5.Image Fusion Using PCA

Source image I1 and source image I2 are arranged in column vectors and empirical mean is used to subtract. Resulting vector is calculated and find Eigen values, Eigen vectors for this resulting vector. Then these eigenvectors are used to compute normalised components D1 and D2.

F (i,j) = D1I1(i,j) + D2I2(i,j)

Transform Domain Techniques

- Discrete Wavelet Transform
- Discrete Cosine Transform
- Lift Wavelet Transform

Discrete Wavelet Transform

In this technique signal is decomposed into low and high frequency bands. This method separates the image into different four frequency bands low-low, low-high, high-low and high-high. Average information holds by low-low frequency band and other bands include directional knowledge about transformation. Discrete wavelet Transform has many features also. It is used in Speech and face recognition. It has many applications in Fingerprint matching etc. It is successful method in transform domain to produce fused image of good quality.

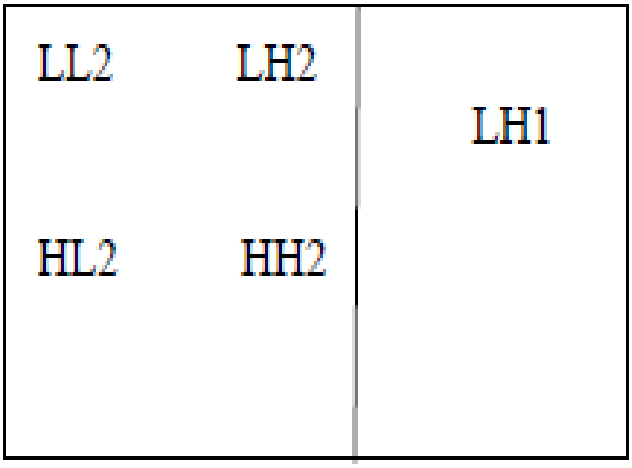

Figure 6.Wavelet Breakdown

Algorithm for DWT technique:

Step 1: Use DWT on each source image and after that decomposition is applied.

Step 2: Each level of decomposition is combined by using techniques like average method, maximum/ minimum method etc.

Step 3: After second step inverse wavelet transform is applied to obtain composite or fused image.

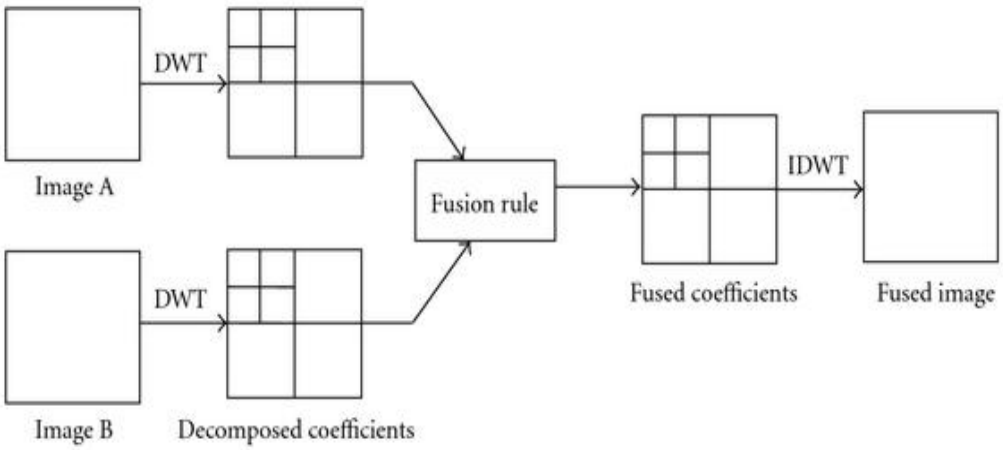

Figure 7.Image Fusion via DWT

Discrete Cosine Transform

This technique is comparable to discrete Fourier transform. But DFT is not suitable for non-stationary signals. In this sine waves are not localized in time and space. Therefore wavelet method is introduced. DCT can divide the image into sub-bands. It can change the signals from spatial to frequency domain.[6,7]

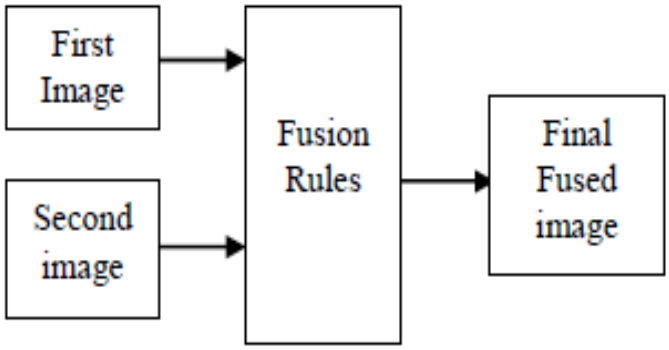

Figure 8.Image Fusion Using DCT

Lift Wavelet Transform

Lifting scheme is a new approach in image fusion and it is wavelet based method. Its main goal is to transform the rough signals into coarse signals. It is effective method for filtering operations. It needs half calculations than conventional DWT method. During decomposition images are decomposed into four frequency bands low-low, low-high, high-high, and high-low. Next decomposition is applied on low-low frequency band of current stage. This lifting scheme is further decomposed in following stages.

- Split
- Predict
- Update

 ISSN: 2395-3802

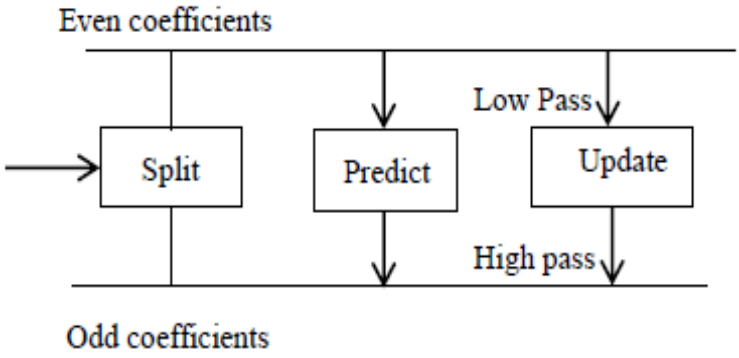

Figure 9.

Split

In this step original data X (n) is divided into two trials which are even coefficients X (e) and odd 1 coefficient X (o) = ∨ ∑((,) − (,))

Predict

In this step detail signals are found by using −1 =1 odd trails and predict operator. It includes the difference of odd and even coefficients. D (n-1) = X (o) – P (X (e))

Update

This stage maintains the global properties of dataset and it contains even coefficients, details signals and 'u' update operator. X (n-1) = X (e) j, I + U (D (n-1))

Quality Evaluation Measures

Peak Signal to Noise Ratio

It is proportion of maximum possible value of signal and power of distorting noise. Higher value of PSNR gives higher visual quality of image [9]. To measure the PSNR we use following formula:

$$PSNR = 20log_{10}\frac{255\sqrt{MN}}{\sqrt{\sum_{i=1}^{M}\sum_{j=1}^{N}\hat{F}((i,j)-F(i,j))^2}}$$

Where F is fused image and M, N is no. of rows and columns respectively. i is index of row and j is index of column.

Standard Deviation

Standard deviation of an image provides an indication of occupied range of the intensity level. It is the square root of variance about mean F. It is calculated by using formula [10]:

$$S.D = \sqrt{\frac{1}{M*N}\sum_{X=1}^{M}\sum_{Y=1}^{N}(I(x,y)-\bar{I})^2}$$

Entropy

The amount of information content in an image is measured by the metric entropy. A higher value of entropy greater variation captured through fusion.[10] The formula for calculation of entropy is:

$$E = -\sum_{i=0}^{L=1} p_i \ log_2 \ p_i$$

Where pi is the probability and ith intensity level

Root Mean Square Error

It calculates the change per pixel that occurs during processing.[11] The formula to calculate RMSE between source images and composite image is given by:

$$RMSE = \sqrt{\frac{1}{XY}\sum_{x-1}^{X}\sum_{y=1}^{Y}(R(x,y)-F(x,y))}$$

Mutual Information

It measures the data that is transferred from one image to another.[12] To calculate transfer information this parameter is best. Mutual information between images is measured by using this formula:

$$I_{MN=}\sum_{xy} P_{MN}\ (x,y)\log\frac{P_{MN}\ (x,y)}{P_M\ (x)P_N\ (y)}$$

In source images Probability density functions are PM (x) and PN (y). Joint probability function is PMN (x, y)

Table 1.Comparison of Different Image Fusion Techniques

Sr. no.	Image fusion method	Area/Domain	Applications/ Features	Merits	Demerits
1.	Select Maximum/ Minimum	Spatial domain method	Simple implementation, gives more focused image if more pixel value.		This technique is pretentious from blurring effect which directly alters the contrast of image
2.	Principle Component analysis (PCA)	Spatial domain method	It decreases the number of measurements and reduces the loss of data.	It removes redundancy present in image	Lesser fusion quality than any of the input images
3.	Discrete Wavelet Transform (DWT)	Transform domain method	It gives high fused quality and it is used in video compression, speech, face recognition etc	Different rules are applied for decomposition on low and high portions of signal	It is not possible to fuse images at different sizes
4.	Discrete Cosine Transform (DCT)	Transform domain method	Extremely simple and energy efficient, suitable for resource constrained battery power sensors for energy efficient fusion	It takes less time for computation as compared to DWT	Fusion quality of this method is not good as DWT.
5.	Lift Wavelet Transform (LWT)	Transform domain method	High speed of computation and save energy for consumption and gives high fused quality	This is best technique over all above DWT, DCT, PCA, MAX/MIN techniques. It gives high quality fused image and takes less computation time	In many cases like multilevel decomposition it can produce little complexity

Conclusion

The combination of the multiple images into single image which contain better description of the scene and gives better quality of composite image is called image fusion. In this article spatial domain and transform domain image fusion techniques are discussed. Spatial domain techniques have some blurring effects and transform domain techniques have good performance than spatial. Transform domain techniques gives good fusion quality of images. LWT has so many advantages over other spatial and transform techniques. This technique provides high fusion quality and high speed of computation. In comparison of these techniques merits and demerits are also discussed. In future disadvantages can be resolved by developing any new method.

References

1. Li M, Dong Y. Review on technology of pixel-level image fusion. International Conference on Measurement, Information and Control, China. 2013. DOI: 10.1109/MIC.2013.6757979.
2. Rahman MA, Liu S, Lin S, et al. Image contrast enhancement for brightness preservation based on dynamic stretching. *International Journal on Image Process* 2016; 9(4): 241.
3. Wang J, Song K, Xiaojun H. Multispectral Image fusion based on the characteristic of imaging system. International Conference on Information and Automation, Yinchuan, China. 2013. DOI: 10.1109/ICInfA.2013.6720375.
4. Desale RP, Verma SV. Study and analysis of PCA, DCT and DWT based image fusion techniques. International Conference on Signal Image Processing and Pattern Recognition (ICSIPR), Coimbatore. 2013. pp. 66-69. DOI: 10.1109/ ICSIPR.2013.6497960.
5. Liu L, Hongyu B, Shao G. An effective wavelet-based scheme for multi-focus image fusion. International Conference on Mechatronics and Automation, Japan. 2013. DOI: 10.1109/ICMA.2013.6618175.

6. Cao L, Longxu J, Tao H. Multi-focus image fusion based on spatial frequency in discrete cosine transform domain. *Signal Processing Letters* 2015; 22(2): 220-4.
7. Garg R, Gupta P, Kaur H. Survey on multi-focus image fusion algorithms. Recent Advances in Engineering and Computational Sciences, Chandigarh. 2014. DOI: 10.1109/RAECS.2014.6799615.
8. Mule MB. Basic medical image fusion methods. *International Journal of Advanced Research in Computer Engineering and Technology* 2015; 4(3): 1046-9.
9. Sonka M, Fitzpatric JM. Handbook of medical imaging-processing and analysis. *International Conference on Medical Imaging* 2001; 20(3): 973-84.
10. Zhang N, Ruan S, Lebonwalet S, et al. Kernal feature selection to fuse multispectral MRI images for brain tumor segmentation. *International Conference on Computer Vision and Image Understanding* 2011; 13: 256-69.
11. Li S, Kwok JT, Wang Y. Multi-focus image fusion using artificial neural networks. *Pattern Recognition Letters* 2002; 23(8): 985-97.
12. Kumar BS. Image fusion based on pixel significance using cross bilateral filter. *Signal, Image Video Processing* 2015; 9(5): 1193-1204.