

Different Image Fusion Techniques and Parameters: A Review

Priya D. Vora

P. G. Student

*Department of Computer Science
Parul Institute of Technology, Vadodara, Gujarat*

Ms. Neeta Chudasama

Assistant Professor

*Department of Computer Science
Parul Institute of Technology, Vadodara, Gujarat*

Abstract -Today in this digital world Image Fusion is the emerging field in the area of Image Processing. Its main goal is to merge two or more images in such a way as to retain the most desirable characteristics of each in resultant image. By observing medical fusion image, doctors could easily confirm the position of illness. In this field of medicine to evaluate or to examine the inner body parts different radiometric scanning techniques can be used. Some most commonly used scanning techniques include Computerized Tomography(CT scan), Magnetic Resonance Imaging scan(MRI) and Position Emission Tomography(PET)but the images of various body parts taken by using these scanning techniques are having their own merits and demerits. The idea of combining images from different modalities become very important and medical image fusion has emerged as a new promising research field. This paper presents two approaches to image fusion, namely Spatial Fusion and Transform Fusion . This paper describes Techniques such as Principal Component Analysis which is spatial domain technique and Discrete Wavelet Transform , Stationary Wavelet Transform which are Transform domain techniques. This paper presents a review on some of the image fusion techniques. Comparison of all the techniques concludes the better approach for its future research.

Keywords-- Image Fusion, Discrete Wavelet Transform (DWT),Stationary Wavelet Transform(SWT), Principal Component Analysis (PCA).

1. INTRODUCTION

Fusion is a process which can be used to improve excellence of information from a set of images. By the process of image fusion the good information from each of the given images is fused together to form resultant image whose quality is superior to any of input images[1]. There are important requirements for image fusion process[4]:

-The fused image should reserve all relevant information from the input images.

-Image fusion should not introduce relics which can lead to wrong diagnosis.

In the field of remote sensing, medical imaging and machine vision the multi-sensor data may have multiple images of the same scene providing different information. As optical lenses in charged coupled devices have limited depth of focus, it is not possible to have a single image that contains all the information of objects in the image, so image fusion is required. There are two groups into which image fusion methods are divided, namely Spatial domain fusion method and Transform domain fusion method. Spatial domain fusion method will directly deal with pixels of input images. In Transform domain fusion method image is first transformed into frequency domain. Use of the

Simple primitive technique will not improve good fused image in terms of performance parameter like peak signal to noise ratio (PSNR), Normalized correlation (NC), and Mean square error (MSE). Recently, Discrete Wavelet Transform (DWT) and Principal Component Analysis(PCA),Morphological processing and Combination of DWT with PCA and Morphological techniques have been prevalent fusion of image[2][3][5].

2. IMAGE FUSION TECHNIQUES

The process of image fusion the good information from each of the given images is fused together to form a resultant image whose quality is greater to any of the input images. Image fusion method can be broadly classified into two groups 1.Spatial domain fusion method. 2.Transform domain fusion method.

In spatial domain techniques, we directly deal with the image pixels.[1] The pixel values are manipulated to achieve desired result.[1]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. Image Fusion applied in every field where images are ought to be analyzed[8]. For example, medical image analysis, microscopic imaging, analysis of images from satellite, remote sensing Application, computer vision, robotics etc [6][7]. The fusion methods such as averaging, Brovey method, principal component analysis (PCA) and IHS based methods fall under spatial domain approaches. Another important spatial domain fusion method is the high pass filtering based technique. The disadvantage of spatial domain approaches is that they produce spatial distortion in the fused image. Spectral distortion becomes a negative factor while we go for further processing such as classification problem [7].

There are numerous methods that have been developed to perform image fusion. Some well-known image fusion methods are listed below [9]:-

- (1) Intensity-hue-saturation (IHS) transform based fusion
- (2) Principal component analysis (PCA) based fusion
- (3) Multi scale transform based fusion:-
 - (a) High-pass filtering method
 - (b) Pyramid method:-
 - (i) Gaussian pyramid
 - (ii) Laplacian Pyramid
 - (iii) Gradient pyramid

- (iv) Morphological pyramid
- (v) Ratio of low pass pyramid
- (c) Wavelet transforms:-
 - (i) Discrete wavelet transforms (DWT)
 - (ii) Stationary wavelet transforms
 - (iii) Multi- wavelet transforms
- (d) Curvelet transforms

1. Principal Component Analysis

Principal component analysis (PCA) is a vector space transform often used to reduce multidimensional data sets to lower dimensions for analysis. PCA is the simplest and most useful of the true eigenvector-based multivariate analyses, because its operation is to reveal the internal structure of data in an unbiased way. If a multivariate dataset is visualized as a set of coordinates in a high-dimensional data space (1 axis per variable), PCA supplies the user with a 2D picture, a shadow of this object when viewed from its most informative viewpoint. This dimensionally-reduced image of the data is the ordination diagram of the 1st two principal axes of the data, which when combined with metadata (such as gender, location etc) can rapidly reveal the main factors underlying the structure of data[10].

Basically Principal component analysis is a method in which number of correlated variables are transformed into number of uncorrelated variables called principal components. A compressed and ideal description of datasets is computed by PCA. The first principal component accounts for as much of the alteration in the data as possible and each succeeding component accounts for as much of the remaining alteration as possible. First principal component is taken to be along the direction with maximum alteration. The second principal component is constrained to lie in the subspace perpendicular to the first within this subspace, this component points the direction of maximum alteration. The third principal component is taken in the direction of maximum variance in the subspace perpendicular to the first two and so on. The PCA is also called as Karhunen-Loève transform or the Hotelling transform. The PCA does not have a fixed set of basis vectors like FFT, DCT and wavelet etc. and its basis vectors depend on the data set[1] [11].

Image fusion process using PCA is described below :

The information flow diagram of PCA-based image fusion algorithm is shown in Fig.1 . $I_1(x, y)$ and $I_2(x, y)$ are the two input images which are to be fused[11].

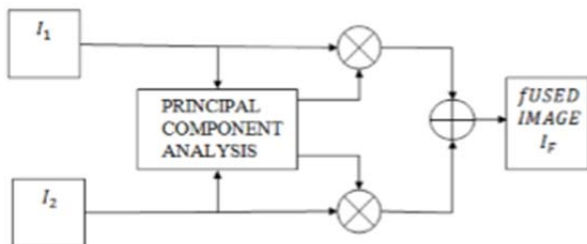


Fig1. Information flow diagram in image fusion scheme employing PCA[1].

-From the input image matrices produce the column vectors.

- Compute the covariance matrix of two column vectors formed before.
- Compute the Eigen values and Eigen vectors of the covariance matrix.
- The column vector corresponding to the larger Eigen value is normalized by dividing each element with mean of Eigen vector.
- Normalized Eigen vector value act as the weight values which are respectively multiplied with each pixel of the input images.
- The fused image matrix will be sum of the two scaled matrices [1].

2. Discrete Wavelet Transform

Wavelet transforms are multi-resolution image decomposition tool that provide a variability of channels representing the image feature by different frequency subbands at multi-scale. It is a famous technique in analyzing signals. When decomposition is performed, the approximation and detail component can be separated 2-D Discrete Wavelet Transformation (DWT) converts the image from the spatial domain to frequency domain. The image is divided by vertical and horizontal lines and represents the first-order of DWT, and the image can be separated with four parts those are LL1, LH1, HL1 and HH1. [12].

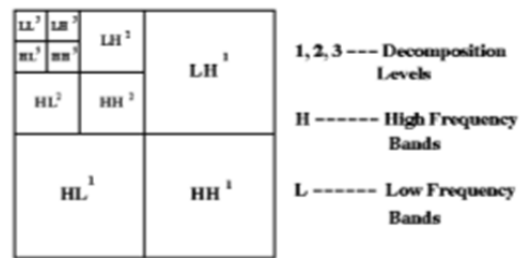


Fig 2. Wavelet decomposition[12]

In discrete wavelet transform (DWT) decomposition, the filters are specially designed so that successive layers of the pyramid only include details which are not already available at the preceding levels.

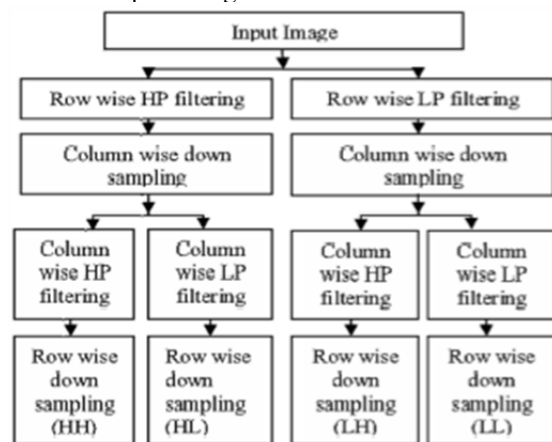


Fig 3. DWT decomposition[1]

The DWT decomposition[13] uses a cascade of special lowpass and high-pass filters and a sub-sampling operation. The outputs from 2D-DWT are four images having size

equal to half the size of the original image. So from first input image we will get HHa, HLa, LHa, LLa images and from second input image we will get HHb, HLb, LHb, LLb images. LH means that low-pass filter is applied along x and followed by high pass filter along y. The LL image contains the approximation coefficients. LH image contains the horizontal detail coefficients. HL image contains the vertical detail coefficients, HH contains the diagonal detail coefficients. The wavelet transform can be performed for multiple levels. The next level of decomposition is performed using only the LL image. The result is four sub-images each of size equal to half the LL image size.[1] Image fusion process using DWT is described below:

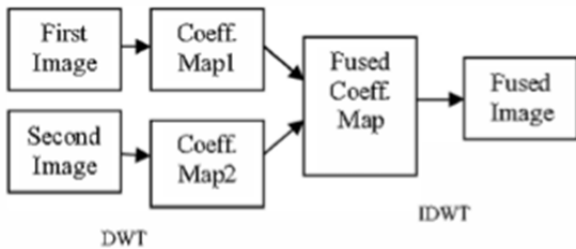


Fig 4. Image fusion process using DWT[1]

Wavelet transform is first performed on each source images to generate a fusion decision map based on a set of fusion rules. The fused wavelet coefficient map can be constructed from the wavelet coefficients of the source images according to the fusion decision map. Finally the fused image is obtained by performing the inverse wavelet transform. The process steps can be given below[13]:

- Accept the two images.
- Perform DWT on both images A and B.
- Perform level 2 DWT on both images A and B
- Let the DWT coefficient of image A will be [HHa HLa LHa LLa].
- Let the DWT coefficient of image B will be [HHb HLb LHb LLb]
- Take the average of pixels of the two band from HHa and HHb and store to HHn.
- Take the average of pixels of the two band from HLa and HLb and store to HLn.
- Take the average of pixels of the two band from LHa and LHb and store to LHn.
- Take the average of pixels of the two band from LLa and LLb and store to LLn.
- Now we have new HHn, HLn, LHn, LLn DWT coefficients. -Take Inverse DWT on the HHn, HLn, LHn, LLn coefficients. -Obtain the fused image and display.

3. Stationary Wavelet Transform

The Discrete Wavelet Transform is not a time- invariant transform. The way to restore the translation invariance is to average some slightly different DWT, called undecimated DWT, to define the stationary wavelet transform (SWT). It does so by suppressing the down-sampling step of the decimated algorithm and instead up-sampling the filters by inserting zeros between the filter coefficients. Algorithms in which the filter is upsampled are called “à trous”, meaning “with holes”. As with the decimated

algorithm, the filters are applied first to the rows and then to the columns. In this case, however, although the four images produced (one approximation and three detail images) are at half the resolution of the original; they are the same size as the original image. The approximation images from the undecimated algorithm are therefore represented as levels in a parallelepiped, with the spatial resolution becoming coarser at each higher level and the size remaining the same[14]. Stationary Wavelet Transform (SWT) is similar to Discrete Wavelet Transform (DWT) but the only process of down-sampling is suppressed that means the SWT is translation-invariant. The 2-D SWT decomposition scheme is illustrated in Figure 5[14].

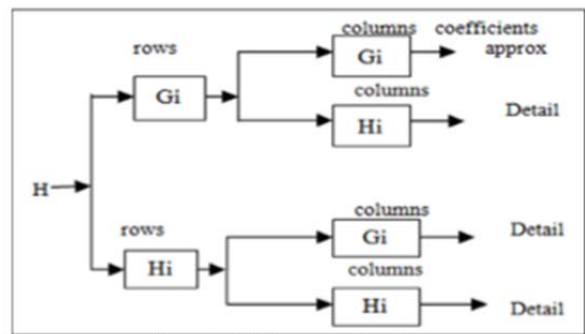


Fig 5. SWT decomposition scheme[1]

The 2D Stationary Wavelet Transform (SWT) is based on the idea of no decimation. It applies the Discrete Wavelet Transform (DWT) and omits both down-sampling in the forward and up-sampling in the inverse transform. More precisely, it applies the transform at each point of the image and saves the detail coefficients and uses the low frequency information at each level. The Stationary Wavelet Transform decomposition scheme is illustrated in Figure 5 where Gi and Hi are a source image, low pass filter and high-pass filter, respectively. Figure 5 shows the detail results after applying SWT to an image using SWT at 1 to 4 levels[14].

Information flow diagram in image fusion scheme employing SWT is as below[1]

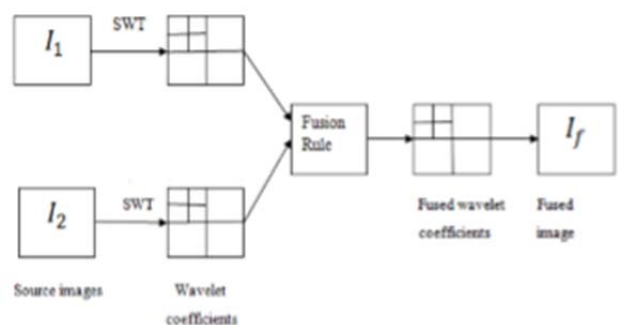


Fig 6. Information flow diagram in image fusion scheme employing SWT[1]

- Processing steps of SWT are as follows[14].
- Decompose the two source images using SWT at one level resulting in three details subbands and one approximation subband (HL, LH, HH and LL bands).
- Then take the average of approximate parts of images.

-Take the absolute values of horizontal details of the image and subtract the second part of image from first.

$$D = (\text{abs}(H1L2) - \text{abs}(H2L2)) \geq 0$$

-For fused horizontal part make element wise multiplication of D and horizontal detail of first image and then subtract another horizontal detail of second image multiplied by logical not of D from first.

-Find D for vertical and diagonal parts and obtain the fused vertical and details of image.

-Same process is repeated for fusion at first level.

-Fused image is obtained by taking inverse stationary wavelet transform.

3. IMAGE FUSION PARAMETERS

The general requirements of an image fusing process are that it should preserve all valid and useful pattern information from the source images, while at the same time it should not introduce artifacts that could interfere with subsequent analyses. The performance measures used in this paper provide some quantitative comparison among different fusion schemes, mainly aiming at measuring the definition of an image[8].

3.1 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 [8][15]. The PSNR measure is given by:-

$$PSNR(dB) = 20 \log \frac{255 \sqrt{3MN}}{\sqrt{\sum_{i=1}^M \sum_{j=1}^N (B'(i,j) - B(i,j))^2}}$$

Where, B - the perfect image, B' - the fused image to be assessed, i - pixel row index, j - Pixel column index, M, N - No. of row and column

3.2 ENTROPY (EN)

Entropy is an index to evaluate the information quantity contained in an image. If the value of entropy becomes higher after fusing, it indicates that the information increases and the fusion performances are improved. Entropy is defined as:-

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

Where L is the total of grey levels, $p = \{p_0, p_1, \dots, p_{L-1}\}$ is the probability distribution of each level [16].

3.3 MEAN SQUARED ERROR (MSE)

The mathematical equation of MSE is given by following equation

$$MSE = \frac{1}{mn} \sum_{i=1}^m \sum_{j=1}^n (A_{ij} - B_{ij})^2$$

Where, A - the perfect image, B - the fused image to be assessed, i - pixel row index, j - pixel column index, m, n - No. of row and column

3.4 NORMALIZED CROSS CORRELATION (NCC)

Normalized cross correlation are used to find out similarities between fused image and registered image is given by the following equation

$$NCC = \frac{\sum_{i=1}^m \sum_{j=1}^n (A_{ij} \cdot B_{ij})}{\sqrt{\sum_{i=1}^m \sum_{j=1}^n (A_{ij})^2}}$$

4. CONCLUSION

In this paper, a method of image fusion is proposed. It is based on the use of Stationary Wavelet Transform, Discrete Wavelet Transform and Principal Component Analysis. By surveying all the techniques with its parameters it is concluded that spatial domain techniques have blurring problem and is overcome by transform domain techniques and out of two techniques of transform domain that is SWT and DWT concluded that SWT gives less PSNR ratio and high MSE and gives better result compared to DWT. In addition our proposed method is to combine the two techniques SWT and DWT of two same domain that is transform domain and will improve the image quality.

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