

Comparison of Image Fusion Techniques: Spatial and Transform Domain based Techniques

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Abstract: *Image Fusion is a process of combining image details from a number of images into a single image, where the resultant fused image will have most of the details and is more informative and complete than any of the input images. Image fusion techniques can increase the quality and populate the application domain of these data. In this paper we present a detailed study and survey on some of the image fusion techniques for image fusion like, primitive fusion (Averaging Method, Select Maximum, and Select Minimum), Discrete Wavelet transform based fusion, Principal component analysis (PCA) based fusion etc. Study and Comparison of all the techniques helps to determine the better approach for its future research and implementation.*

Keywords: Principal Component Analysis (PCA), Discrete Wavelet Transform (DWT), Mean Square Error (MSE), Normalized correlation (NC), Peak signal to noise ratio (PSNR), Laplacian Fusion.

1. Introduction

Image fusion is the one of most desired quality for CCTVs and Multi sensor imaging. It means the combining of two images into a single image that has the maximum information content without producing details that are non-existent in the given images[1][2].

With fast advancements in technology, now a days it is possible to obtain information from multi source images to produce a high quality fused image with spatial and spectral information [2] [3]. Image Fusion is a mechanism to improve the quality of information from a set of images. Important applications of the fusion of images include medical imaging, microscopic imaging, remote sensing, computer vision, and robotics .

Use of the Simple primitive technique will not recover good fused image in terms of performance parameter like peak signal to noise ratio (PSNR), Normalized correlation (NC), and Men 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 popular fusion of image[4][5][6].

These methods are shown to perform much better than simple averaging, maximum, minimum.

2. Various Image Fusion Techniques

In the process of image fusion the higher quality and clearer version of information from each of the given images is combined together to form a resultant image whose quality is superior to any of the input images .

Image fusion method can be classified into two groups –

1. Spatial domain fusion method - It directly deals with the image pixels. The pixel values are altered to achieve desired result. The fusion methods such as averaging, Brovey method, principal component analysis (PCA) and IHS based methods fall under spatial domain approaches.

2. Transform 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.

Image Fusion is helpful in various fields like medical imaging, microscopic imaging, analysis of images from satellite, remote sensing Application, computer graphics vision, robotics etc. [7][8].

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 [8].

The problem of Spatial distortion can be overcomed by frequency domain approaches on image fusion. The multi

resolution analysis a very useful tool for analysing remote sensing images in space.

Some other fusion methods are also there such as Laplacian- pyramid based, Curvelet transform based etc. These methods show a better performance in spatial and spectral quality of the fused image compared to other spatial methods of fusion [8].

The Types of various image fusion techniques are [3]:-

- (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

3. Image Fusion Algorithm

Due to the limited focus length of the optical lens it is often not possible to get an image that contains all relevant objects in focus. To obtain an image with every object in focus a multi-focus image fusion process is required to fuse the images giving a better view for human or machine perception. Pixel-based, region-based and wavelet based fusion algorithms were implemented [9].

3.1. Simple Average

It is a well-documented fact that regions of images that are in focus tend to be of higher pixel intensity. Thus this algorithm is a simple way of obtaining an output image with all regions in focus. The value of the pixel P (i, j) of each image is taken and added. This sum is then divided by 2 to obtain the average. The average value is assigned to the corresponding pixel of the output image which is given in equation (1). This is repeated for all pixel values.

$$K(i, j) = \{X(i, j) + Y(i, j)\} / 2 \quad (1)$$

Where X (i, j) and Y (i, j) are two input images.

3.2 Select Maximum

The greater the pixel values the more in focus the image. Thus this algorithm chooses the in-focus regions from each input image by choosing the greatest value for each pixel, resulting in highly focused output. The value of the pixel P (i, j) of each image is taken and compared to each other. The greatest pixel value is assigned to the corresponding pixel [7] [9].

3.3 Discrete Wavelet Transform (DWT)

Wavelets are finite duration oscillatory functions with zero average value [1]. They have finite energy. They are suited for

analysis of transient signal. The irregularity and good localization properties make them better basis for analysis of signals with discontinuities.

Wavelets can be described by using two functions viz. the scaling function f (t), also known as „father wavelet“ and the wavelet function or „mother wavelet“. Mother wavelet (t) undergoes translation and scaling operations to give self-similar wavelet families as given by Equation.

$$\psi_{a,b}(t) = \frac{1}{\sqrt{a}} \psi\left(\frac{t-b}{a}\right), (a, b \in R), a > 0 \quad (2)$$

The wavelet transform decomposes the image into low-high, high-low, high-high spatial frequency bands at different scales and the low-low band at the coarsest scale which is shown in fig: 2.

The L-L band contains the average image information whereas the other bands contain directional information due to spatial orientation. Higher absolute values of wavelet coefficients in the high bands correspond to salient features such as edges or lines [1][7][10]. The basic steps performed in image fusion given in fig. 1.

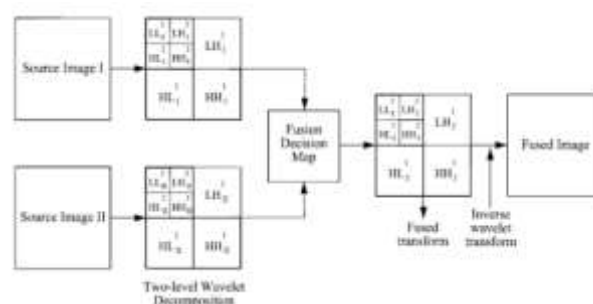


Fig. 2: Wavelet Based image fusion

The wavelets-based approach is appropriate for performing fusion tasks for the following reasons:-

- (1) It is a multi-scale (multi resolution) approach well suited to manage the different image resolutions. Useful in a number of image processing applications including the image fusion [3] [7].
- (2) The discrete wavelets transform (DWT) allows the image decomposition in different kinds of coefficients preserving the image information. Such coefficients coming from different images can be appropriately combined to obtain new coefficients so that the information in the original images is collected appropriately.
- (3) Once the coefficients are merged the final fused image is achieved through the inverse discrete wavelets transform (IDWT), where the information in the merged coefficients is also preserved.

3.4 Principal Component Analysis (PCA)

PCA is a mathematical tool which transforms a number of correlated variables into a number of uncorrelated variables. The PCA is used extensively in image compression and image classification. The PCA involves a mathematical

procedure that transforms a number of correlated variables into a number of uncorrelated variables called principal components. It computes a compact and optimal description of the data set.

The first principal component accounts for as much of the variance in the data as possible and each succeeding component accounts for as much of the remaining variance as possible. First principal component is taken to be along the direction with the maximum variance. The second principal component is constrained to lie in the subspace perpendicular of the first.

Within this Subspace, this component points the direction of maximum variance. The third principal component is taken in the maximum variance direction 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 [11].

4. Performance Metrics

The most important requirements of an image fusion process are that it should preserve all valid and original information from the source images, while at the same time it should not introduce artifacts. The performance metrics used are PSNR, EN, MSE and NCC.

4.1 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 [2][9]. The PSNR measure is given by:-

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

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.

4.2 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:-

$$E = - \sum_{i=0}^{L-1} p_i \log_2 p_i \quad (4)$$

Where L is the total of grey levels, p = {p₀, p₁, p_{L-1}} is the probability distribution of each level [9].

4.3 Mean Squared Error (MSE)

The mathematical equation of MSE is giver by the equation (5)

$$MSE = \frac{1}{mn} \sum_{i=1}^m \sum_{j=1}^n (A_{ij} - B_{ij})^2 \quad (5)$$

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.

4.4 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 (6)

$$NCC = \frac{\sum_{i=1}^m \sum_{j=1}^n (A_{ij} * B_{ij})}{\sum_{i=1}^m \sum_{j=1}^n (A_{ij})^2} \quad (6)$$

5. Comparison Between Various Fusion Techniques

In the reference [9],[12] we found that the value of the PSNR and Entropy in average method is less than as compared to value of other frequency domain method like SWT and Laplacian method which means fused image are not exactly to registered image. That is why transform domain method are more suitable as compared to spatial domain method. But in some case Spatial domain play a very important role in image fusion that contain high spatial information in fused image. Same thing is also noticed in [2] and [4]. Table is given below.

S. No.	Technique	Domain	Measuring Parameters
1	Simple Average[12][9]	Spatial	PSNR, EN
2	Simple Maximum[8][12]	Spatial	PSNR, EN
3	PCA[11]	Spatial	NC, PSNR
4	DWT [3][4][8]	Transform	RMSE, EN
5	Combined DWT and PCA [7][9]	Transform	PSNR, EN
6	Combine of Pixel & Energy Fusion Rule [2]	Transform	PSNR

Table 1. Comparison of Techniques.

6. Conclusion

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 transforms is the very good technique for the image fusion provide a high quality spectral content. But a good fused image have both quality so the combination of DWT & spatial domain fusion method (like PCA) fusion algorithm improves the performance as compared to use of individual DWT and PCA algorithm.

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