A Review on Fusion Techniques for Fingerprint Recognition

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Abstract: This paper describes some of the fusion techniques for fingerprint recognition. Image Fusion is a process of combining the relevant information from a pair of fingerprint images into a single image. The fused fingerprint image carries more information and any loss with respect to ridges in either of the fingerprint image will be completed. Image fusion techniques can improve the quality in most of the techniques. The literature review on some of the image fusion techniques such as Multi Resolution Singular Value Decomposition (MSVD), Discrete Stationary Wavelet Transform (DSWT), Dual Tree Complex Wavelet Transform (DT-CWT) and Discrete Wavelet Transform (DWT) etc with respect to fingerprint image are discussed. Comparison of all the techniques concludes the better approach for its future research.

Keywords: Fusion, recognition, information, technique, fingerprint

I. INTRODUCTION

Image Fusion is a process of combining the relevant information of two images into a single image. The idea behind fusion is to minimize the memory requirement to store the fingerprint image in the database for future purpose. As well any loss in the ridges of fingerprint image can be retrieved there by improves the clarity of ridges in the fused image. Image Fusion is needed 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, robotics etc. Use of the Simple primitive technique will not recover good fused image in terms of performance parameter like Peak signal to noise ratio (PSNR), Men square error (MSE) and Root mean square error (RMSE). Recently, Discrete Wavelet Transform (DWT) and Multi Resolution Singular Value Decomposition (MSVD), Discrete Stationary Wavelet Transform (DSWT), Dual Tree Complex Wavelet Transform (DTCWT) techniques have been popular fusion of image. These methods are shown to perform much better than simple averaging, maximum, minimum.

Image fusion is performed at different levels according to the stage at which the fusion takes place, namely pixel level fusion, feature level fusion, match score level fusion and decision level fusion.

i) Pixel level fusion: It process directly the pixel information from individual sensor and the most basic method used for fusion.

ii) Feature level fusion: It is a process of augmenting the feature vectors arising from multiple feature extractors and subjecting the fused feature vector to a feature transformation algorithm [13].

iii) Match score level fusion: It is classified into three categories such as Statistical fusion, learning based fusion and Evidence theory based fusion [4].

iv) Decision level fusion: It is the simplest form of fusion that uses only the final outputs of individual sub-systems [13].

Before performing the fusion, the images have to be converted into spatial or transform domain. The various image fusion methods are depicted as in Figure 1.Spatial domain directly deals with the image pixels. The pixel values are manipulated to achieve desired results. They produce spatial distortion in the fused image. Examples are PCA, HIS, SVD, Laplacian pyramid based, Curvelet transform. In Transform or Frequency domain, image is transferred into Fourier transform, and a fusion operation is performed and then applies inverse Fourier transform. This method is computationally very simple and used in real time applications. Examples are WT, MSVD, and MFFT.There is various methods that have been developed to perform image fusion. Some well-known image fusion methods are listed below in figure 1 [1].

II. RELATED WORK

The performance of the image fusion by MSVD is almost similar to that of wavelets. It is computationally simple, well suited for real time applications and has a fixed set of basis vectors like FFT, DCT and wavelet etc [2]. In Multi-resolution singular value decomposition signal is filtered separately by low pass and high pass finite impulse response (FIR) filters and the output of each filter is decimated by a factor of two to achieve first level of decomposition. The decimated low pass filtered output is filtered separately by low pass and high pass filter followed by decimation by a factor of two provides second level of decomposition. The successive levels of decomposition can be achieved by repeating this procedure. The idea behind the MSVD is to replace the FIR filters with singular value decomposition (SVD). [2]

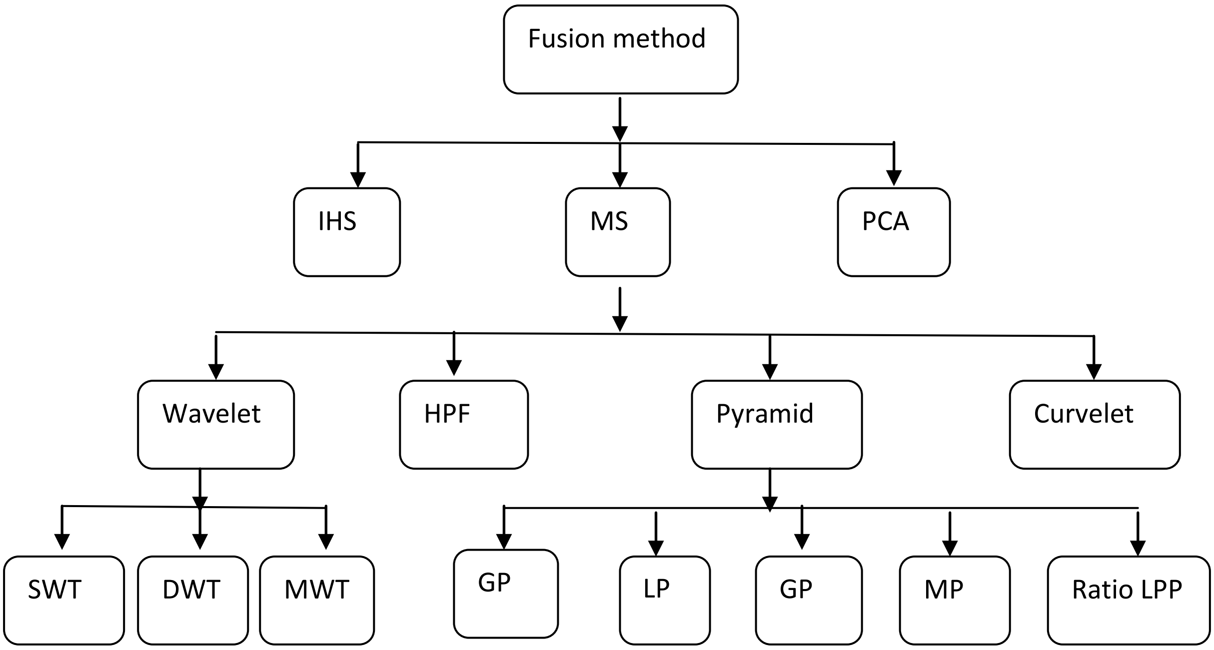

Figure1. Fusion methods

Multi-resolution image analysis by Fast Fourier Transform (MFFT) is to apply simple and proven technique of FFT to pixel level image fusion. The performance of image fusion by MFFT is slightly better than wavelet based image fusion. It is computationally very simple, well suited for real time applications. [3]

This technique can be used to fuse multi fusion aspect images as well. Different orientation images must be registered before fuse them. If the sources images are of different sizes (resolutions) decompose the images into different levels and wherever the sizes match, then fuse them. If one of the source images is colour and other is gray image, then convert the colour image into gray and then fuse them. [3]

Evidence theoretic multimodal fusion approach using belief functions that takes into account the variability in image characteristics. When processing non-ideal images the variation in the quality of features at different levels of abstraction may cause individual classifiers to generate conflicting genuine-impostor decisions. Existing fusion approaches are non-adaptive and do not always guarantee optimum performance improvements. Compared to existing fusion algorithms, it is computationally efficient, and the verification accuracy is not compromised even when conflicting decisions are encountered. [4]

Fusion method based on D-S evidence theory is proposed to combine fingerprint information together for personal identification. The performance of the proposed algorithm can well solve the evidence conflict problem and effectively improve the precision and performance of fingerprint identification. However, these methods have some inherent limitations in accuracy due to the quality variations of fingerprint images. [5]

Image Fusion is a process of combining the relevant information from a set of images, into a single image, where in the resultant fused image will be more informative and complete than any of the input images. The PCA & DCT are conventional fusion techniques with many drawbacks, whereas DWT based technique provides better results for image fusion. Two algorithms based on DWT are proposed, pixel averaging & maximum pixel replacement approach. [6]

Image fusion using hierarchical PCA combines pyramid and PCA techniques. Hierarchical multi scale and multi resolution image processing techniques, pyramid decomposition are the basis for the majority of image fusion algorithms. PCA is a well-known scheme for feature extraction and

dimension reduction and is used for image fusion. The proposed image fusion using hierarchical PCA is better for the fusion of multimodal images. [6]
The multimodal fused image using hierarchical PCA algorithm is more informative than the fused image using individual pyramid or PCA algorithm. Multi-modal, multi-sensor and multi-focus images can be effectively fused using hierarchical PCA, pyramid and wavelet based fusion approaches respectively. [7]
As the limited depth-of-focus of optical lenses, it is usually difficult to get an image that contains all information of the objects in focus. Multi-focus image fusion method can solve this problem effectively. A new multi-focus image fusion method is based on curvelet transform; we use the maximum local energy method to calculate the energy of two images.
Firstly, the coefficients of two different focus images are obtained by curvelet transform; Secondly, select the low-frequency coefficients by maximum local energy, and through a sliding window, obtained output the Maximum energy pixel information. Then the high-frequency coefficients are gotten by absolute maximum method; finally, the fused image was obtained by performing an inverse curvelet transform. The performance of curvelet transform is better and it exhibits high directional sensitivity and is highly anisotropic Compared with wavelet transform method, median pyramid method. [8]
The information content of a single image is mainly limited by the spatial and spectral resolution of the imaging system. Current imaging systems offer a trade-off between high spatial and high spectral resolutions. No single system offers both of these characteristics, to obtain the both characteristics in a single image, a novel method for multimodality remote sensing image fusion technique can be employed. As a possible remedy for this problem we propose a technique for the fusion of Panchromatic and Multispectral images based on Curvelet transform. This paper introduces new application of the curvelet in multispectral remote sensing image fusion. The Performance of this method results in merged images with improved quality and preserves more spectral features with less spatial distortion with respect to those obtained by IHS, DWT, wavelet, ridgelet and curvelet transform. [9].
Wavelet analysis is derived from the Short Time Fourier Transform (STFT), it is time-frequency analysis method featuring multi-resolution analysis. Owing to its characteristic of time-frequency localization, wavelet analysis is widely used in the image processing field. The combination of the wavelet transform and the traditional HIS transform has been used and the HIS transform fusion method also causes great improvements on spectral distortion. The remote sensing images to be processed involve a great deal of data, complicated algorithms cause too long operation time and consume more system resources. The combination of the wavelet transform and the traditional HIS transform has significant advantages because it operates quickly and realizes easily [10].
The aim of the image fusion is to integrate the characteristic information of each image, By uniting the useful information a new image can be formed to improve the visual impression, and one can get a more accurate, comprehensive and reliable description for the same scene. Traditional IHS transforms method results in the spectral distortion. So an image fusion method based on HSV colour space model and wavelet transform (HSV+WT) has been proposed on the basis of the method which is based on IHS transform and wavelet transform (IHS+WT). The Performance of the HSV+WT method is better than the result of the IHS+WT method and that the low frequency coefficient fusion method is feasible.[11].
The objective of fusion is to generate an image which describes a scene better or even higher than any single image with respect to some relevant properties providing an informative image. These fusion techniques are important in diagnosing and treating cancer in medical field. image fusion method using Dual Tree Complex Wavelet Transform results shows that proposed algorithm has a better visual quality than the base methods. The DT-CWT based fusion is having better value of PSNR and least MSE when compared to other fusion methods. [12]

III. METHODOLOGY:

The four different algorithms of fingerprint fusion are implemented. They are as follows

3.1. Multiresolution Singular Value Decomposition (MSVD)

Multi-resolution singular value decomposition [2] is very similar to wavelets transform, where signal is filtered separately by low pass and high pass finite impulse response (FIR) filters and the output of each filter is decimated by a factor of two to achieve first level of decomposition. The decimated low pass filtered output is filtered separately by low pass and high pass filter followed by decimation by a factor of two provides second level of decomposition [2]. The successive levels of decomposition can be achieved by repeating this procedure. The idea behind the MSVD is to replace the FIR filters with singular value decomposition (SVD).
The images to be fused I_1 and I_2 are decomposed into L (l =1,2,..., L) levels using MSVD. At each decomposition level (l =1,2,..., L) , the fusion rule will select the larger absolute value of the two MSVD detailed coefficients, since the detailed

coefficients correspond to sharper brightness changes in the images such as edges and object boundaries etc. These coefficients are fluctuating around zero. At the coarest level ($l = L$) , the fusion rule take average of the MSVD approximation coefficients since the approximation coefficients at coarser level are the smoothed and subsampled version of the original image. Similarly, at each

$$X \rightarrow \left\{ \Phi_L,\ \{\Psi_l\}_{l=1}^{L},\ \{U_l\}_{l=1}^{L} \right\} \qquad (2)$$

Let U_1 be the eigenvector matrix

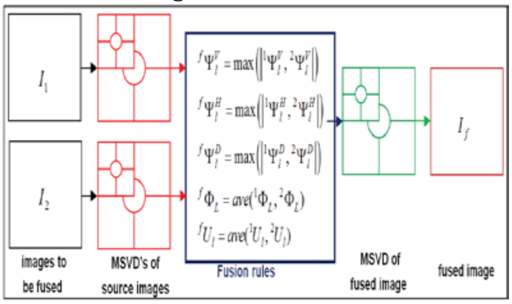

Figure 2. Schematic diagram for the MSVD image fusion.

Parameters of Interest:

1. Mean Square Error (MSE)
2. Root Mean Square Error(RMSE)
3. Peak Signal To Noise Ratio(PSNR)

3.2. Discrete Wavelet Transform (DWT)

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.

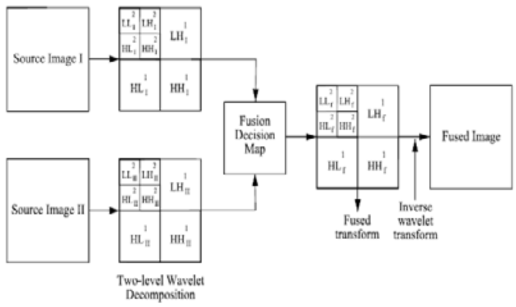

Figure 3. Image Fusion Process using DWT

1,2,3 are Decomposition levels
H is High Frequency Bands
L is Low Frequency Bands
The detailed fusion steps based on wavelet transform can be summarized as shown in Figure 3.

decomposition level (l =1,2,..., L) , the fusion rule take the average of the two
MSVD eigen matrices. The fused image I_f can be obtained using:

$$I_f \leftarrow \left\{ {}^f\Phi_L,\ \left\{ {}^f\Psi_l^V,\ {}^f\Psi_l^H,\ {}^f\Psi_l^D \right\}_{l=1}^{L},\ \left\{ {}^fU_l \right\}_{l=1}^{L} \right\} \qquad (1)$$

1. First register the input images (I1 and I2), which are going to be fused and corresponding pixels are aligned.
2. The Registered input images are decomposed into wavelet transformed images respectively, based on haar wavelet transformation (W). The transformed images with K-level decomposition will include one low-frequency portion (LL band) and 3K high-frequency
by applying performing an inverse wavelet transform (W-1) based on the combined portions (LH bands, HL bands and HH bands).
3. The Transform coefficients of different portions are performed with a certain fusion rule.
4. Then transform coefficients, the fused image (I) is constructed.

3.3 Stationary Wavelet Transform

The Discrete Wavelet Transform is is a translation-variant transform. The way to restore the translation invariance is to average some slightly different DWT, called decimated 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 up-sampled are called “à trous”, meaning “with holes”. In this 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 as shown in Figure 4. The un-decimated algorithm is redundant, meaning some detail information may be retained in adjacent levels of transformation. It also requires more space to store the results of each level of transformation and, although it is shift-invariant, it does not resolve the problem of feature orientation. A previous level of approximation, resolution J−1, can be reconstructed exactly by applying the inverse transform to all four images at resolution J and combining the resulting images. Essentially, the inverse transform involves the same steps as the forward transform, but they are applied in the reverse order[14].

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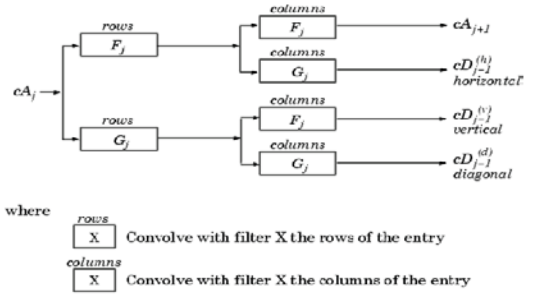

Figure 4. Stationary Wavelet Transform decomposition scheme

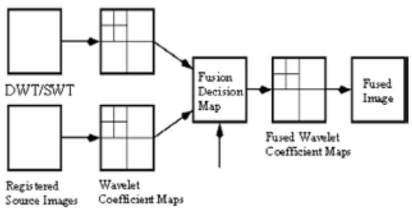

Figure 5. DWT/SWT based image fusion

Let A (x, y) and B (x, y) are images to be fused. The decomposed low frequency sub images of A (x, y) and B (x,y) be respectively lAJ (x, y) and lBJ (x, y) (J is the parameter of resolution). The decomposed high frequency sub images of A(x,y) and B(x,y) are hAjk (x, y) and hBjk (x, y). (j is the parameter of resolution and j=1,2,3….J for every j, k=1,2,3..).Then, the fused high and low frequency sub-images Fjk (x, y) are given as Fjk (x, y) = Ajk (x, y) if G(Ajk (x, y)) >= G(Bjk (x,y)), else Fjk (x, y) = Bjk (x, y) and FJ (x, y) = lAJ (x, y) if G(AJ(x, y)) >= G(BJ (x, y)), else FJ (x, y) = lBJ (x, y) where G is the activity measure and Fjk (x, y) & FJ (x, y) are used to reconstruct the fused image F¢(x, y) using the inverse stationary wavelet transform. The block diagram representing the stationary wavelet based image fusion is shown in Figure 5.

3.4. Dual Tree Complex Wavelet Transform

In Dual Tree Complex Wavelet Transform (DT-CWT), fusion is performed using the masks to extract information from the decomposed structure of DT-CWT. Figure 6 shows the complex transform of a signal using two separate DWT decompositions: Tree a and Tree b.

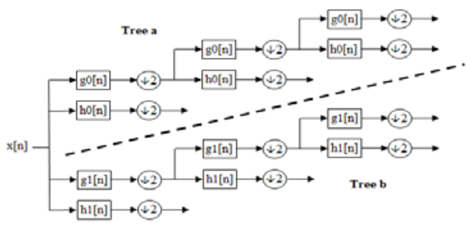

Figure 6. DT-CWT based image fusion

DT-CWT structure, involves both real and complex coefficients. It is known that DT-CWT is relevant to visual sensitivity. Fusion procedure involves the formation of a fused pyramid using the DT-CWT coefficients which are obtained from the decomposed pyramids of the source images.
The fused image is obtained through conventional inverse dual tree complex wavelet transform or reconstruction process. This results show a significant reduction of distortion.

IV. EVALUATION CRITERIA

There are three evaluation measures used in this paper, they are as follows,

4.1 Mean Square error

The mathematical equation of MSE is giver by the equation

$$MSE = \frac{1}{mn}\sum_{i=1}^{m}\sum_{j=1}^{n}(A_{ij} - B_{ij})^2 \quad (3)$$

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

4.2 Root Mean Square Error

RMSE= sqrt (MSE) (4)

4.3 Peak Signal to Noise Ratio

The signal to Noise ratio between the reference image *R* and fused image *F* is given by,

PSNR= 10log 10 (255) ^2/MSE (db) (5)

The methods proposed for implementing image fusion takes the following form in general. The two source images to be fused are assumed to be registered spatially. The images are fused using singular value decomposition and wavelet transformed using the same wavelet, and transformed to the same number of levels. For taking the MSVD and wavelet transform of the two images, readily available MATLAB routines are taken. In each sub-band, individual pixels of the two images are compared based on the fusion rule that serves as a measure of activity at that particular scale and space. A fused wavelet transform is created by taking pixels from that wavelet transform that shows greater activity at the region level. The inverse transform is the fused image with clear focus on the whole image.
For the above mentioned methods, image fusion is Performed using MSVD, DWT, DSWT and DT-CWT and their performance is measured in terms of Mean Square Errors, Peak Signal to Noise Ratio, and the fused results are shown in figure 4 and tabulated in table1.

Table 1: Comparison between various fusion techniques

Sl. no	Fusion Technique	MSE	RMSE	PSNR
1	MSVD	7696.6	84.26	8.925
2	DWT	**2424.9**	**48.99**	**14.401**
3	DSWT	2544.06	49.1	13.9
4	DTCWT	530180763	17197.2	-16.36

V. CONCLUSION

This paper presents the comparison of all levels of image fusion using MSVD, DWT, DSWT and DTCWT in terms of various performance measures. DWT provides very good results both quantitatively and qualitatively for pixel level fusion. DSWT provides computationally efficient and better results among MSVD and DTCWT. Hence using these fusion methods, one can implement using HDL and can be implemented on fpga and matching is performed for better results in fingerprint recognition.

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