A novel approach to Image Fusion using combination of Wavelet Transform and Curvelet Transform

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Abstract— Panchromatic furthermore multi-spectral image fusion outstands common methods of high-resolution color image amalgamation. In digital image reconstruction, image fusion is standout pre-processing step that aims increasing hotspot image quality to extricate all suitable information from source images ruining inconsistencies or artifacts. Around the different strategies available for image fusion, Wavelet and Curvelet based algorithms are mostly preferred. Wavelet transform is useful for point singularities while Curvelet transform, as the name describes, is more useful for the analysis of images having curved shape edges. This paper reveals a study of development in the field of image fusion.

Key words: Image Fusion, Wavelet, Curvelet

I. INTRODUCTION

Image processing is the science of processing images with the help of mathematical operations making use of any kind of signal processing for which an image is an input, such as photograph or a video frame, delivering the output in form of an image or a set of characteristics or parameters related to the input image. Treating the image as a two-dimensional signal and applying standard signal processing techniques is majorly adopted by image-processing techniques. Along with digital image processing, optical as well as analog image processing is also possible.

Image fusion is a process that unites the relevant information or data from a set of images and the fused image obtained as a result will be more informative and complete than any of the input images individually. Input images can be multimodal, multi sensor, multi focus or multi temporal. There are some grievous requirements for the image fusion process.

- The fused image should perpetuate all pertinent information from the source images.
- The image fusion should not acquaint artifacts that might lead to wrong diagnosis.

One of the significant pre-processing steps for image fusion is image registration, i.e. the process of modifying assorted sets of data into a single coordinate system.

A. Need of Image Fusion:

Image acquisition is normally accomplished by a device focusing on a particular portion of scene leaving the other portion blurred. As optical lenses in charged coupled devices have a modest or say limited depth of focus, it is not possible to have a single image that contains all the information of the objects in the scene. Image fusion belongs to a scope of information fusion, refers to the same scene received from different sensors or at different times from same sensors, using appropriate processing methods and some sort of fusion technologies/strategies to obtain a composite image. Multiple image fusion can overcome the limitations and differences in sensor geometry, spatial and spectral resolution of a single image, improve the quality of the image, thus contributing to locate, identify and explain the physical phenomena and events.

1) Image Fusion Levels:

According to application purpose of image fusion it can be divided in to pixel level, feature level and decision level fusion.

a) Pixel Level:

The figure below describes the steps of pixel level image fusion:

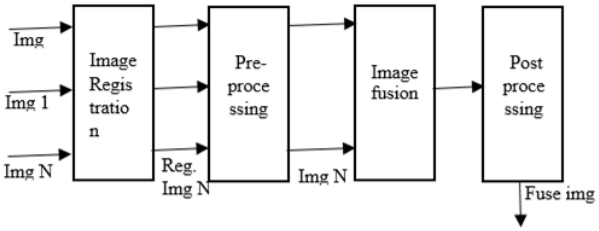

Fig. 1: Pixel level image fusion.

Applying pre-processing expeditiously pull off known artifacts introduced by the input sensors and substantially alleviate system's performance. The post processing is resolute by the type of display and the purpose of fusion system.

b) Feature Level:

Feature level fusion needs extraction of features from the input images. Features may be pixel intensities or texture and edges features. The assorted features are advised depending on the nature of the image and the application form of the fused image. It requires extraction of features like edges, shape, regions, length, size or image segments, and features with correspondent intensity in the image to be merged/fused from different types of images of the exact same area. These features are then merged with similar features present in other input image by a way of pre-determined selection method to get the final fused image.

c) Decision Level Fusion:

This level of fusion is very high level, which involves combining the results from multiple algorithms to yield a final fused image.

2) Domains of Image Fusion:

The image fusion techniques are basically bifurcated into two domains i.e.

- Spatial domain techniques ex. PCA etc.
- Transform domain techniques ex. Wavelet, Curvelet etc.

a) PCA:

Principal Component Analysis is a vector space transform usually used to reduce multidimensional data sets to lower dimensions for analysis. It is the simplest, most useful of the true eigenvector- based multivariate analyses as its operation is to unveil the internal structure of data in an unbiased way.

Fundamentally PCA is a technique that transforms a number of correlated variables into number of uncorrelated variables called principal components. 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 left over variance as possible.

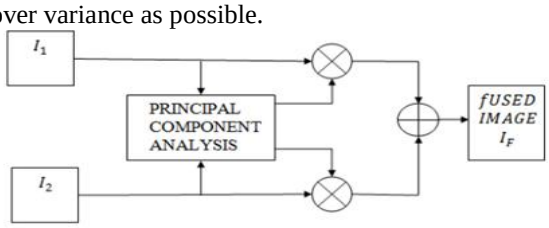

Fig. 2 Information flow diagram employing PCA[4]

b) Wavelet Transform:

Wavelet theory is an extension of Fourier theory in many aspects and is familiarized as an alternative to the short time Fourier transform (STFT). A wavelet is a small wave that grows and decays basically in a limited time period. 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[4].

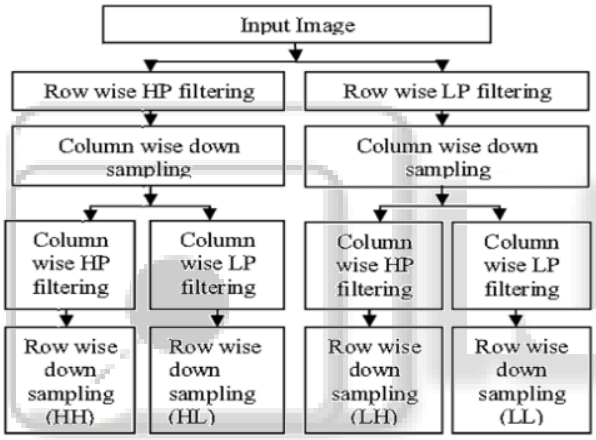

Fig. 3: DWT decomposition[4]

The DWT decomposition uses a cascade of special low-pass and high-pass filters and sub-sampling operations. The outputs from 2D-DWT are four images having size equal to half the size of the original input image. These four images are LL, LH, HL and HH respectively, where "L" means Low and "H" means High. HL means that high pass filter is applied along x and followed by low pass filter applied along y, and vice versa for LH. The LL image is called approximation whereas remaining three is called details. LL image contains approximation coefficients, LH contains the horizontal detail coefficients, HL image contains the vertical detail coefficients and HH contains the diagonal detail coefficients.

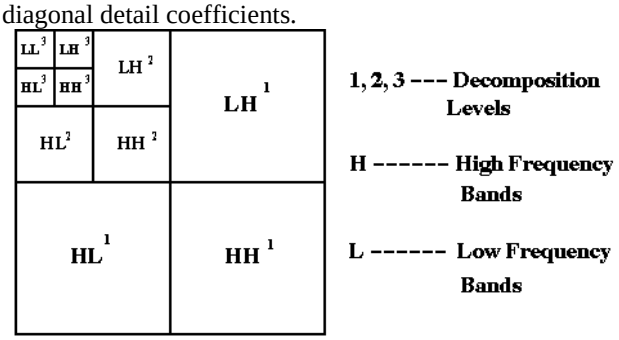

Fig. 4: DWT decomposition image

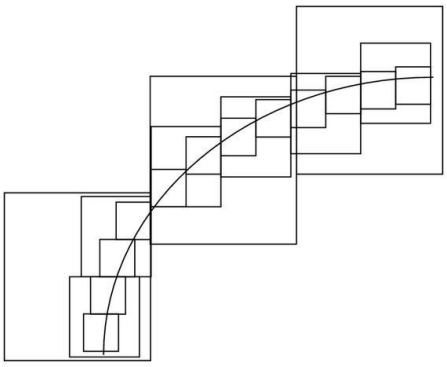

Fig. 5: Number of coefficients needed to account edge in wavelet transform

c) Curvelet transform:

Curvelet transform was developed on the basis of wavelet transform. It overcomes the defects of wavelet transform that is unable to characterize the directional properties of the image edges. Good directionality and anisotropy is the main feature, which can provide more information for image processing, and can accurately capture the edges of the image to a different scale and different frequency sub-bands[2].

Curvelet transform can provide sparse expression for both edge portions and smooth portions on the image simultaneously. In addition to Wavelet transform's traditional characteristics that provides characteristic of "point", the Curvelet transform, due to the high directional feature, it can get description for the features directly on the line, and even the variation characteristics of high-dimensional plane.

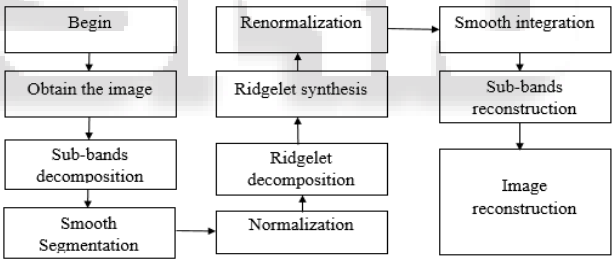

Fig. 6: Flow diagram of Curvelet transforms

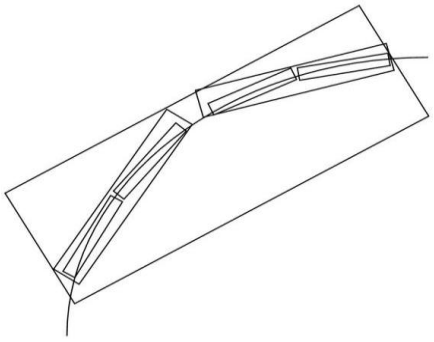

Fig. 7: Number of coefficients needed to account edge in Curvelet transform

II. LITERATURE SURVEY

It has been noticed that transform domain methods are mostly preferred over spatial domain methods because spatial domain methods have blurring problem and transform domain methods provide high a high quality spectral content.

A. Multiresolution Image Fusion Approach for Image Enhancement[1]

In 2015, authors Deepali Sale, Rajshree Bhokare and Dr. Madhuri A Joshi proposed a method to analyze the performance of multi-wavelet transform methods. They have compared the results of both the algorithms. They performed this on human palm.

As they say, a human palm contains rich information used to recognize individuals. In addition to the superficial features in a palm, there is presence of subsurface features i.e. palm veins, visible under infrared lights. While palm lines are comparatively thin, they are in dense presence over the palm. On the other hand, palm veins are thick, while their pattern may be quite sparse over the same region. The availability of such complementary features i.e. palm lines and veins allows for increased discrimination between the individuals. Using multispectral imaging (MSI), it is possible to simultaneously capture images of an object in the visible spectrum and beyond.

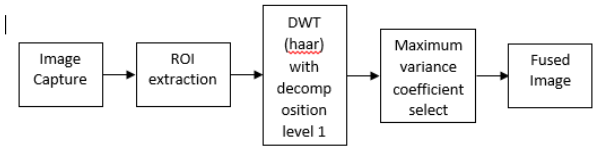

Fig. 8: Multispectral palm image fusion system.

A region of interest (ROI) will be extracted from the palm image which can reduce the influence of rotation and translation of the palm. Thus, no more registration procedure is necessary.

1) Algorithm for Wavelet based Image Fusion

- Input red palm, green palm, blue palm and near infrared images.
- Apply haar wavelet transform with single level decomposition.
- Calculate approximate, horizontal, vertical and diagonal components of the input image.
- For every A, V, H, D components calculate variance of image using 3x3 window.
- Add cumulatively the variance of all the blocks.
- Compare the variance of the components and select the component with the largest variance.
- Image with larger variance contains more information, which will enhance information content in the resulting palm print image.

2) Algorithm for Curvelet Based Image Fusion

- Input red palm, green palm, blue palm and near infrared images.
- Calculate Curvelet components of red, green, blue and infrared palm images.
- Extract the entire Curvelet component from its structure.
- For every component calculate variance of images. Compare the variances of components and select the components with largest variance. Image with a larger variance contains more information, which will enhance the information content in the resulting palm print image.
- Gather all components with highest variance to get single structure.
- Inverse Curvelet transform is obtained to get the fused image.
- Authors have made the quality assessment on the basis of average gradient, edge intensity, Shannon entropy and standard deviation.

B. High Quality Multispectral And Panchromatic Image Fusion Technologies Based On Curvelet Transform[2]

In 2015, authors Limin Dong, Qingxiang yang, Haiyong Wu, Huachao Xiao and Mingliang Xu had proposed an algorithm that combines the advantages of IHS (Intensity Hue Saturation) transform and Curvelet transform, used standard deviation method fusion rules, process new fusion algorithm for panchromatic and multispectral image quality. The specific algorithm is as follows

1) Enlarge the multispectral image by bilinear interpolation, consistent with the panchromatic image size, and perform spatial registration.
2) Perform histogram matching for the three band multispectral image according to panchromatic images.
3) Perform HIS transform on the three multispectral image, generate I, H, S 3 components; perform Curvelet transform on component 'I' and panchromatic image respectively, generate dominant coefficient c(x,y) and 'J' sub-band coefficients $\omega_j(x,y)$

$$I(x,y) = c(x,y) + \sum_{j=1}^{J} \omega_j(x,y)$$

4) Use standard deviation method to fuse the component 'I' and dominant coefficient c(x,y) of panchromatic image decomposition.
5) Combine dominant coefficient after fusion c'(x,y) and sub-bands coefficient $\omega_j(x,y)$ of panchromatic image, then perform Curvelet transform synthesis, and obtain the component I after the fusion.
6) Perform IHS inverse transform on three components I', H, S to obtain the high resolution color image.

The above method can save spectral characteristics better and can store spatial information as well.

Quality assessment is done on the basis of Image information entropy, average gradient, correlation coefficient, Errur relative adimensionnelle synthese and UIQI (Universal Image Quality Index).

C. Wavelet and Curvelet transform based Image Fusion Algorithm[3]

In this paper, 2014, the author Shriniwas T. Budhewar had proposed a method for image fusion based on Wavelet and Curvelet transform that follows a generic method as shown in fig. 9.

After fusion, reverse transform is applied to get image back in spatial domain.

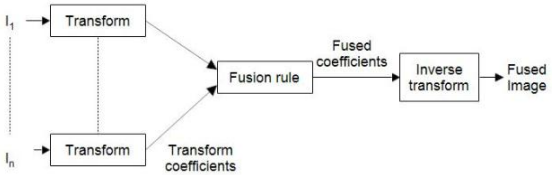

Fig. 9: Generic method for transform based fusion[3]

The algorithm is shown in fig. 10. For this experiment the author has derived raw images from a single image, by blurring either left or right side of image. Left blurred image can be treated as right focused image and vice versa.

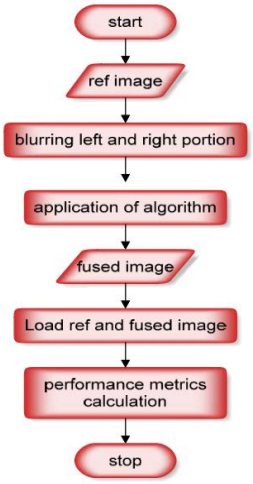

Fig. 10: Image fusion algorithm[3]

Quality assessment was done on the basis of following factors: Peak signal to noise ratio (PSNR), standard deviation, entropy, root mean square error and cross correlation.

D. Comparative study of Image Fusion Technologies based on Spatial and Transform Domain[4]

In 2014, authors Sweta K. Shah and Prof. D.U. Shah had compared the image fusion technologies: Principal Component Analysis (PCA) i.e. based on spatial domain and Discrete Wavelet Transform & Stationary Wavelet Transform that are transform domain technologies.

The discrete wavelet transform is not time invariant transform. The way to restore the translation invariance is to average some slightly different DWT, called un-decimated DWT, to define the Stationary Wavelet Transform (SWT).

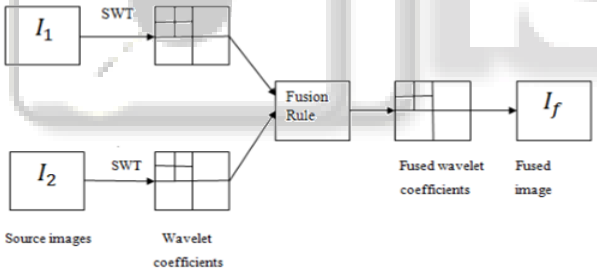

Fig. 11: Information flow diagram in image fusion scheme employing SWT[4]

Fusion performance was measured on the image quality evaluation metrics: Spatial Frequency (SF) and standard deviation. SF indicated the overall activity in the fused image. Higher the SF means better the performance.

E. A Novel Approach for Pixel Level Image Fusion Based On Curvelet Transform[5]

In this paper of 2013, the authors, Navneet Kaur and Jaskiran Kaur had proposed a method for image fusion for medical images, as shown in fig. 12. They had used Log Gabor filter in this method. Benefits of using log Gabor filter is

- No DC component.
- Improves contrast ridges and edges.
- Enables to obtain wide spectral information with localized spatial extent.
- Helps preserve true ridge structures of image.

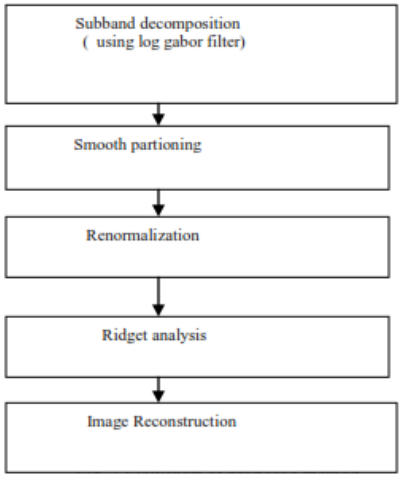

Fig. 12: Flow Chart of the Proposed Method[5]

To evaluate the performance of the image fusion process they had used four metrics i.e. PSNR, standard deviation, entropy and Quality.

III. Application Area of Image Fusion

- Navigation Aid
- Medical Imaging
- Remote Sensing
- Merging out-of-focus images
- Robotics
- Manufacturing
- Military and law enforcement

IV. Advantages

- High resolution of fused images.
- Reduce blurring effect.
- High details
- Better night vision images
- Better infrared images

V. Disadvantages

- Techniques lack precision.
- More than one technique has to be used for better results.
- Time consuming for large sized images (Satellite images).

VI. Conclusion

From the above literature we can conclude that transform based techniques are better compared to spatial based techniques. Also Wavelet is useful in extracting linear edges effectively whereas Curvelet is giving better results as far as curved edges are concerned. Both have their own limitations, however it can be resolved by combining the advantages of both the techniques in an efficient way.

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