Image Fusion using Improved Contourlet Transform Technique

Nupur Singh, Pinky Tanwar

Abstract- ***Image fusion is the process by which two or more images are combined into a single image retaining the important features from each of the original images. The fusion of images is often required for images acquired from different instrument modalities or capture techniques of the same scene or objects .Several approaches to image fusion can be distinguished, depending on whether the images are fused. The purpose of image fusion is to combine information from several different source images to one image, which becomes reliable and much easier to be comprehended by people (Youcef and Amrane,2003). Image fusion can be broadly defined as the process of combing multiple input images or some of their features into a single image without the introduction of distortion or loss of information. The objective of image fusion is to combine complementary as well as redundant information from multiple images to create a fused image output. Therefore, the new image generated should contain a more accurate description of the scene than any of the individual source image and is more suitable for human visual and machine perception or further image processing and analysis tasks.***

Index Terms— ***LFS, HFS, ICNT, CNT, ALM.***

I. INTRODUCTION

All Image fusion can be divided into three levels: pixel-level fusion, feature-level fusion, and decision-level (Tang and Pu ,2006). Image fusion at pixel-level means fusion at the lowest processing level referring to the merging of the measured physical parameters and its application is very wide. At the level it have the details on the information which other levels do not have (Wu,Wang and Li ,2010) The data level fusion is also called pixel level fusion, which means the direct process of data taken from sensors. It is the foundation of high level image fusion and one important direction of present image fusion research. The merit of this fusion method is keeping the living original data as much as possible, which provides the details that other level fusion methods cannot supply (Zhang and Hu , 2010) .

Feature-level fusion is done in the course of image feature extraction. It's the medium level fusion and prepared for decision-level fusion. In the process of feature-level fusion, features of every image are extracted. The same kind of features of different images is organically synthesized. The typical features are edge, shape, profile, angle, texture, similar lighting area and similar depth of focus area. While fusing features, the forms and contents of main features are correlative with the applied purpose and situation of image fusion. Decision-level fusion is the highest-level fusion. All decision and control are decided according to the results of decision-level fusion.

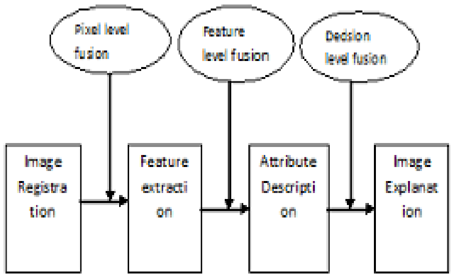

Figure1. Basic Levels of Image Fusion [2]

A. PIXEL LEVEL IMAGE FUSION

First, Pixel-level fusion is operated in the phase of image pre-processing. Pixel-level fusion is able to provide the detail information of image that can not be brought by those at the other levels. The purpose is to obtain a further clear image, which is involved in more information. Pixel-level fusion is a low level fusion. Before fusing images, image registration of original images must be done. Pixel-level fusion is divided into two parts, signal-level and image-point fusion. Signal-level fusion refers to synthesize a group of signals offered by sensors. The purpose is to obtain high-quality signals, which format is consistent with the original. Image points of every image are directly synthesized in the process of image-point fusion. The pixel-level fusion determines the value of each pixel based on a set of pixels from the source images .Pixel-level fusion is to fuse on the raw data layer with strict registration conditions, and carry out data integration and analysis before the raw data of various sensors being pre-processed. Pixel-level image fusion is the lowest level of image fusion, which is to keep more raw data as much as possible to provide rich and accurate image information other fusion levels can not provide, so that the image will be easy to be analyzed and processed, such as image fusion, image segmentation and feature extraction, etc. The images to participate the fusion may com from multiple image sensors with different types, also may from a single image sensor the original images must be registered at first. Image registration is the process of matching two or more images that get from the same scene derived from different time, different sensors or different views of angle Pixel-level fusion can be

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broadly divided into two categories .One is spatial domain image fusion method and the other is the rate of frequency domain image fusion method.

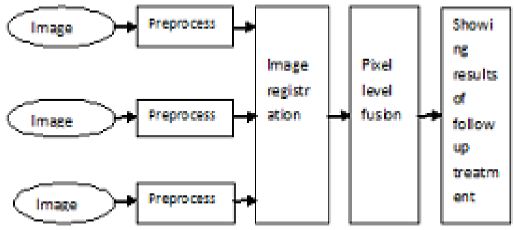

Figure 2. Pixel level image fusion flow (Hui and Binbin ,2009)

Image registration includes the four following contents, feature space, searching space, searching strategy and measurement of similarity. There are many methods of image registration. The three common used methods are method base on pixel registration, on feature registration and on model registration. Image registration is the base of image fusion, movement detection and tridimensional vision. It precision directly influences the results of subsequent process. The quality of fused image is also influenced by the registration precision. Image registration is the bottleneck of improvement of precision and efficiency in multi-waveband image fusion. The most useful information is preserved and every pixel's information is enhanced.

B. Medical Image Fusion

In recent years, multimodality medical image fusion has drawn lots of attention with the increasing rate at which multimodality medical images are available in many clinic application fields (Shu Xia and Xun Zhang,2009)with the rapid development in high-technology and modern instrumentations, medical imaging has become a vital component of a large number of applications, including diagnosis, research, and treatment. The medical image fusion is to integrate multiple images, such as CT, MRI, and PET images, into a composite image that contains more effective information for diagnoses. Image fusion can take place at the pixel, feature, and symbol level .In order to support more accurate clinical information for physicians to deal with medical diagnosis and evaluation, multimodality medical images are needed, such as X-ray, computed tomography (CT), magnetic resonance imaging (MRI), magnetic resonance angiography (MRA), and positron emission tomography (PET) images. These multimodality medical images usually provide complementary and occasionally conflicting information. For example, the CT image can provide dense structures like bones and implants with less distortion, but it cannot detect physiological changes, while the MR image can provide normal and pathological soft tissues information, but it cannot support the bones information. In this case, only one type of image may not be sufficient to provide accurate and complete clinical requirements for the physicians. Therefore, the fusion of the medical images is necessary . For medical image fusion, the fusion of images can often lead to additional clinical information not apparent in the separate and different images. Another advantage is that it can reduce the storage cost by storing just the single fused image instead of multisource images Generally, medical image fusion means the matching and fusion between two or more images of the same lesion area from different medical imaging equipment, and aims to obtain complementary information and increase the amount of information. Medical image fusion technique is to combine the information of a variety of images with computer-based image processing method. the same part of the same patient with different imaging devices, and the information provided by a variety of imaging modes is often complementary . In the medical images, CT can clearly reflect the anatomical structure of bone tissues. Oppositely, MRI can clearly reflect the anatomical structure of soft tissues, organs and blood vessels. CT, MRI and other modes of medical images reflect the human information from various angles. In the clinical diagnosis and treatment, the problems about the comparison and synthesis between image CT and MRI were frequently encountered. Both CT and MRI are the effective methods for the diagnostics of craniocerebral diseases. As a result of different imaging principles, CT and MRI would clearly display the different information of the same anatomizing structure (Shen and Ma ,2006) .To solve the problem, we utilized the fusion algorithm.

C. Conventional Methods of Image Fusion

Spatial Domain Methods

The term spatial domain refers to the image plane itself and approaches in this category are based on direct manipulation of pixels in an image. Spatial domain processes can be denoted by the expression as given by eq

$$g(x, y) = T[f(x,y)]$$

where f (x, y) is the input image, g (x, y) is the processed image and T is an operator on f, defined over some neighborhood of (x, y). One of the principle approaches in this formulation is based on the use of so-called masks (also referred to as kernels, templates, windows or filters). A mask is a small 2-D array in which the values of the mask coefficients determine the nature of the process, such as image sharpening.

The various spatial domain techniques are illustrated below:

1)Average Method :

The most simplest way of image fusion is to take the average of the two images pixel by pixel. Averaging work well when the images to be fused are from the same type of sensor and contain additive noise (Sabari 2011).

Advantages

- It is very simlpe method.
- It is easy to understand and implement .
- Averaging works well when images to be fused are from same type of sensor and contain additive noise.
- This method proves good for certain particular cases where in the input images have an overall high brightness and high contrast.

Disadvantages

- It leads to undesirable side effect such as reduced contrast.
- With this method some noise is easily introduced into the fused image, which will reduce the resultant image quality consequently.
- It can lead to a stabilization of the fusion result and this scheme tends to blur images and reduce the contrast of features appearing in only one image

2) Brovey Transform :

Brovey transform (BT) , also known as color normalized fusion, is based on the chromaticity transform and the concept of intensity modulation .It is a simple method to merge data from different sensors, which can preserve the relative spectral contributions of each pixel but replace its overall brightness with the high spatial resolution image .As applied to three MS bands, each of the three spectral components (as RGB components) is multiplied by the ratio of a high-resolution co-registered image to the intensity component I of the MS data .The formula is shown as follows (Yang and Han ,2007)

$$IMG_{I} = IMG_{low\ i}\ IMG_{high}\ ,\ i = 1,2,3 \qquad (2)$$

Where $IMG_{low\ i}$, i = 1,2,3 denote three selected MS band image ,IMG_{high} for high resolution image ,and IMG_{i} for fusion image corresponding to IMG_{low} , i = 1,2,3 and the intensity component refers to I as shown in Eq.(2)

$$I = (IMG_{low1} + IMG_{low2} + IMG_{low\ 3}) /3 \qquad (3)$$

Advantages

- it is a simple method to merge the data from different sensors.
- This method is simple and fast.
- It provide superior visual and high resolution multispectral image.
- This method is very useful for visual interpretation..

Disadvantages

- This method ignore the requirement of high quality synthesis of spectral information.
- It produces a spectral distortion

3) Intensity Hue Saturation (IHS)

It is most popular fusion methods used in remote sensing. The fusion is based on the RGB-IHS conversion model, whose various mathematical representations have been developed .No matter which conversion model is chosen, the principle of the IHS transformation to merge images attributes to the fact that the IHS color space is catered to cognitive system of human beings and that the transformation owns the ability to separate the spectral information of an RGB composition in its two components H and S, while isolating most of the spatial information in the I component. In this method three MS bands R, G and B of low resolution Image are first transformed into the IHS color coordinates, and then the histogram - matched high spatial resolution image substitutes the intensity image which describes the total color brightness and exhibits as the dominant component a strong similarity to the image with higher spatial resolution. Finally, an inverse transformation from IHS space back to the original RGB space yields the fused RGB image, with spatial details of the high resolution image incorporated into it .The intensity I defines the total colour brightness and exhibits as the dominant component . After resolution using the high resolution data , the merge result is converted back into the RGB After applying an IHS transformation on the low spatial resolution images, we replace the Intensity component by the high spatial resolution image The fused images are obtained by applying a reverse IHS transformation on the new set of components (He ,Wang and Amani ,2004)

$$\begin{bmatrix} I \\ V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} 1/\sqrt{3} & 1/\sqrt{3} & 1/\sqrt{3} \\ 1/\sqrt{6} & 1/\sqrt{6} & -2/\sqrt{6} \\ 1/\sqrt{2} & -1/\sqrt{2} & 0 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

$$H = \tan^{-1}[\ v_2/v_1]\ ,\ S = \sqrt{(v_2)^2 + (v_2)^2} \qquad (4)$$

I refers to intensity , H and S stands for hue and saturation ,while v1 and v2 represents intermediate variables which are The needed in the transform . IHS transform is a method used to display and enhance images as well as integrating information. It is flexible and practical. The IHS transform has the following functions:

- Synthetically display the remote sensing images with different resolutions
- Make the composite images more saturated
- Enhance images by filtering the intensity
- Make it easy to synthetically display multi-source Data (Wu and Li ,2009)

Advantages

- It provide high spatial quality.
- It is a simple method to merge the images attributes.
- It provide a better visual effect.
- It gives the best result for fusion oh remote sensing images.

Disadvantages

- It produces a significant colour distortion with respect to the original image.
- It suffers from artifacts and noise which tends to higher contrast.
- The major limitation that only three bands are involved.

4) *Principle Component analysis (PCA)*

This technique, also known as the Karhunen-Loeve transform, is extensively used in image encoding, image data compression, image enhancement and image fusion for various mapping and information extraction . The PCA method is similar to the IHS method, with the main advantage that an arbitrary number of bands can be used (Wang , Ziou and Armenaki ,2005). The processing program of data fusion by method is as follow:

First, the multi-spectral image is transformed with PCA transform and the eigenvalues and corresponding eigenvectors of correlation matrix between images in the multi-spectral image's individual hands are worked out to obtain each matrix's principle components.

Second, the image is matched by the first principle component using histogram method. Finally, the first principle component of the multi-spectral image is replaced with the matched image and with other principle components, is transformed with inverse PCA transform to form the fused image (Cao ,Li and Zhang ,2003).

After applying a PCA transformation on the low spatial resolution images, we replace the first component by the high spatial resolution image. The fused images are obtained by applying an inverse PCA transformation on the new set of components . In the context of image fusion, it performs an orthogonal linear transformation on the image of the original N-dimensional variables which is given below

$$y = A(x - m_x) \quad (5)$$

where x refers to original *N* source images, *y* refers to the transformed new uncorrelated images, and A refers to *N* ×*N* transformation matrix. The covariance matrix of original source transformed images and the transformation matrix satisfies.

$$C_y = AC_xA^T = \begin{bmatrix} \lambda_1 & & & 0 \\ & \lambda_2 & & \\ & & \ddots & \\ 0 & & & \lambda_N \end{bmatrix}$$

(6)

Where Cx refers to the N ×N covariance matrix of original N source images, Cy refers to the N ×N transformed new uncorrelated images. The rows of the transformation matrix A consists of normalized orthonormal eigenvectors corresponding to eigen values λi , i □ □ 1,_,N with the descending order. Through such a de correlation scheme, the new uncorrelated variables of a much smaller dimensionality M (M<N) can be generated in the new coordinate system by minimizing the mean square error introduced by neglecting N - M of the transformed components.

$$e_{ms} = \sum_{j=1}^{N} \lambda_j - \sum_{j=1}^{M} \lambda_j = \sum_{j=M+1}^{N} \lambda_j \quad (7)$$

Then an inverse PCA transformation on the new uncorrelated M-dimension variables back to the original image space can obtain an approximation of *x* by performing (Gonalez,1994).

$$\hat{x} = A_M^T y_M + m_x \quad (8)$$

above equation refers to the reconstruction of original source images.

Advantages

- This method is very simple to use and the images fused by this method have high spatial quality.
- It prevents certain features from dominating the image because of their large digital numbers.

Disadvantages

- It sufers from spectral degradation
- This method is highly criticized because of the distortion of the spectral characteristic entailed between the fused images and the original low resolution images. Consequently, the resulting image does not preserve faithfully the colours found in the original images

5) *Artificial Neural Network (ANN)*

Inspired by the fusion of different sensor signals in biological systems, many researchers have employed artificial neural networks in the process of pixel-level image fusion. The most popular example for the fusion of different imaging sensors in biological systems is described by Newman and Hart line in the 80s: Rattlesnakes (and the general family of pit vipers) possess so called pit organs which are sensitive to thermal radiation through a dense network of nerve fibers. The output of these pit organs is fed to the optical spectrum, where it is combined with the nerve signals obtained from the eyes. Newman and Hart line distinguished six different types of bimodal neurons merging the two signals based on a sophisticated combination of suppression and enhancement .The performance of ANN depends on the sample images and this is not a characterstics

Transform Domain Method

Transform domain processing techniques are based on modifying the Fourier transform of image.

1) *Pyramid Method*

Image pyramids have been initially developed for multiresolution image analysis and as a model for the binocular fusion in human vision. A generic image pyramid is a sequence of images where each image is constructed by low pass filtering and sub sampling from its predecessor. Due to sampling, the image size is halved in both spatial directions at each level of the decomposition process, thus it leads to an multiresolution signal representation. The difference between the input image and the filtered image is so much necessary to allow an exact reconstruction from the pyramidal representation. The image pyramid approach thus leads to a signal representation with two pyramids: The smoothing pyramid containing the averaged pixel values, and the difference pyramid containing the pixel differences which is edges .So we can say that the difference pyramid can be viewed as a multiresolution edge representation of the input image. The basic idea is to construct the pyramid transform of the fused image from the pyramid transforms of the source images, and then the fused image is obtained by taking inverse pyramid transform.

Most of the pyramid structures are based on the Gaussian pyramid (GP) Successive levels of a Gaussian pyramid can be generated by a REDUCE operation . Let G0 be the bottom level of the pyramid, i.e., the original image IMG , Gl be the l level. Then

$$G_l = REDUCE(G_{l-1}) = (w * G_{l-1})_{\downarrow 2}, G_0 = IMG \quad (9)$$

where w denotes the lowpass filtering operation on the l -1 level. And ↓2 denotes the subsampling operation by a factor of 2. An inverse operation of REDUCE defined as EXPAND can construct a new image Gl,1 with the same size to Gl-1 through interpolation and lowpass filtering. Thus we have

$$Gl.k = EXPAND(Gl,k-1)=(w*Gl,k-1)\uparrow 2 ,Gl,0 = Gl \quad (10)$$

where Gl,k denotes the result of expanding G l k times (0 ≤ k ≤ l). Gl,k-1 denotes the k level of the operation on the l −1 level from l level. And ↑2 denotes the interpolation operation.

The decade of 1980's saw the introduction of pyramid transform (Krishnamoorthy and Soman ,2010) a fusion method in the transform domain. The basic idea is to construct the pyramid transform of the fused image from the pyramid transforms of the source images and then the fused image is obtained by taking inverse pyramid transform (Sadjadi ,2005) . An image pyramid consists of a set of lowpass or bandpass copies of an image, each copy representing pattern information of a different scale. Typically, in an image pyramid every level is a factor two smaller as its predecessor, and the higher levels will concentrate on the lower spatial frequencies. An image pyramid does contain all the information needed to reconstruct the original image (Burt ,,1992). Typically, every pyramid transform consists of three major phases .

- Decomposition
- Formation of the initial image for recomposition.
- Recomposition.

According to different methods of the pyramid image fusion algorithm, tower structure fused algorithms can be divided into Gaussian pyramid , Laplace pyramid, gradient pyramid, ratio of low-pass pyramid and the morphological pyramid (Wu,Wang and Li ,2010). The Gaussian pyramid is a sequence of images in which each member of the sequence is a low pass filtered version of its predecessor (Olkhonen and Resole ,1996) . Laplacian pyramid of an image is a set of band pass images , in which each is a band pass filtered copy of its predecessor. Band pass copies can be obtained by calculating the difference between lowpass images at successive levels of a Gaussian pyramid (Burt and Adelson ,1983). A gradient pyramid (GP) of an image can be obtained by apply gradient operator in four directions to each level of its Gaussian pyramid. However, to reconstruct the image, the gradient pyramid, filter-subtract-decimate (FSD) pyramid and the Laplacian pyramid are all need to be computed (Burt and kolczynski,1993) .Ratio of Low Pass Pyramid is another pyramid in which at every level the image is the ratio of two successive levels of the Gaussian pyramid (Toet,1996).

A morphological pyramid is obtained by applying morphological filters to the Gaussian pyramid at each level and taking the difference between 2 neighboring levels. A morphological filer is usually for noise removal and image smoothing. It is similar to the effect of a low-pass filter, but it does not alter shapes and locations of objects in the image. The morphological pyramid fusion is therefore the same as the fusion using Laplacian pyramid method except replacing the Laplacian pyramid with the morphological pyramid (Zang ,Sayedelahl and Gilmore 2006) .

Advantages

- It shows better performance in spatial and spectral quality of the fused image compared to the other spatial method
- It can provide information on the sharp contrast changes, and human visual system is especially sensitive to these sharp contrast changes.
- It can provide both spatial and frequency domain localization.

Disadvantages

- It creates the blocking effects.
- During fusion creates undesired edges.
- It does not provide any directional information

II. PROBLEM FORMULATION

The major drawback of the contourlet construction is that its basis images are not localized in the frequency domain. In the current , we analyze the cause of this problem, and propose a new contourlet construction as a solution. Instead of using the Laplacian pyramid, we employ a new multiscale decomposition defined in the frequency domain. The resulting basis images are sharply localized in the frequency domain and exhibit smoothness along their main ridges in the spatial domain.

A. Methodology and Algorithm

It forms a multiresolution directional tight frame designed to efficiently approximate images made of smooth regions separated by smooth boundaries. The Contourlet transform has a fast implementation based on a Laplacian Pyramid decomposition followed by directional filterbanks applied on each bandpass subband. Medical Image Fusion (MIF) method, based on a novel combined Activity Level Measurement (ALM) and

Contourlet Transform (CNT) for spatially registered, multi-sensor, multiresolution medical images. The source medical images are first decomposed by CNT. The low-frequency subbands (LFSs) are fused using the novel combined ALM, and the high-frequency subbands (HFSs) are fused according to their 'local average energy' of the neighborhood of coefficients. Then inverse contourlet transform (ICNT) is applied to the fused coefficients to get the fused image.However Laplacian Pyramid decomposition can be removed with the help of multiscale sharp frequency localization Here is the proposed algorithm:

B. Algorithm

The medical images to be fused must be registered to assure that the corresponding pixels are aligned. Here we outline the salient steps of the proposed Method which exclude the Laplacian Pyramid decomposition :

1) Decompose the registered source medical images A and B by multiscale decomposition so that images are sharply localized in the frequency domain and exhibit smoothness along their main ridges in the spatial domain.

2) Fused the coefficients of LFSs using the combined ALM to get the fused LFS.

3) Similarly to get the fused HFSs, fuse the HFSs of the images A and B, using fusion rule

4) Apply inverse contourlet transform on the fused LFS and HFSs to get the final fused medical image.The block diagram of the proposed MIF scheme is shown :

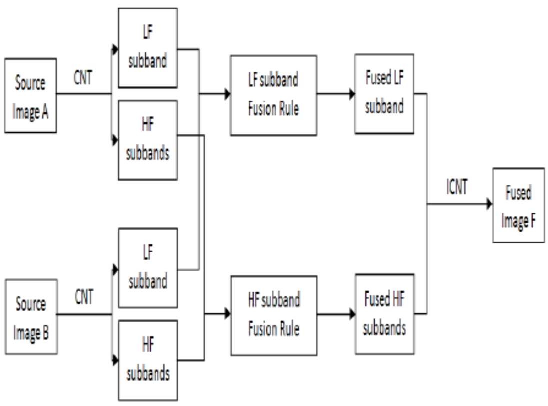

Figure 3. Block Diagram of the proposed MIF method.

Above is the proposed method. In this we are replacing pyramid decomposition to make image much smoother.

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