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An Efficient Method of Pan-sharpening using NSCT

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***Abstract*—There has been an exponential increase in satellite image data availability. Image data are now collected with dissimilar spatial, spectral, and temporal resolutions. Image fusion techniques are used extensively to combine different images having corresponding information into one single composite. The fused image has rich information that will improve the performance of image analysis algorithms. Pan-sharpening is a pixel level fusion technique used to increase the spatial resolution of the multispectral image using spatial data from the high resolution panchromatic image while preserving the spectral data in the multispectral image. Resolution merge, image integration, and multisensor data fusion are some of the equivalent terms used for pan-sharpening. The pan-sharpening using NSC Transform is the powerful technique for satellite multispectral image enhancement. NSCT is very efficient in representing the directional information and capturing intrinsic geometric structures of the objects and it has characteristics of high resolution, shift invariance, and high directionality. The system simulated result shows that used method provides better resolution in these images rather than prior approaches.**

***Index Terms*—Image Enhancement, Non-subsampled Contourlet Transform, Pan-sharpening Technique.**

I. Introduction

Earth observation satellites provide data casing different parts of the electromagnetic spectrum at different spatial, spectral, and temporal resolutions. To make use of these different types of image data effectively, a number of image fusion techniques have been established [1]. Image synthesis is the set of methods, tools and, means of using data from two or more different images to advance the quality of the info [2]. The increase in quality of the information leads to enhanced processing (ex: classification, segmentation) accuracies compared to using the information from one type of data alone.

Image fusion takes place at three different levels: pixel, feature, and decision [1]. In pixel-level fusion, a new image is made whose pixel values are got by combining the pixel values of different images through some algorithms. The new image is then used for more processing like feature extraction and classification. In feature-level fusion, the features are taken out from unlike types of images of the same geographic area. The extracted features are then classified using statistical or other types of classifiers. In decision-level fusion, the images are processed discretely. The processed info is then developed by combining the information obtained from different sources and the differences in info are fixed based on certain decision rules. Figure 1.provides a visual interpretation of the different levels of fusion

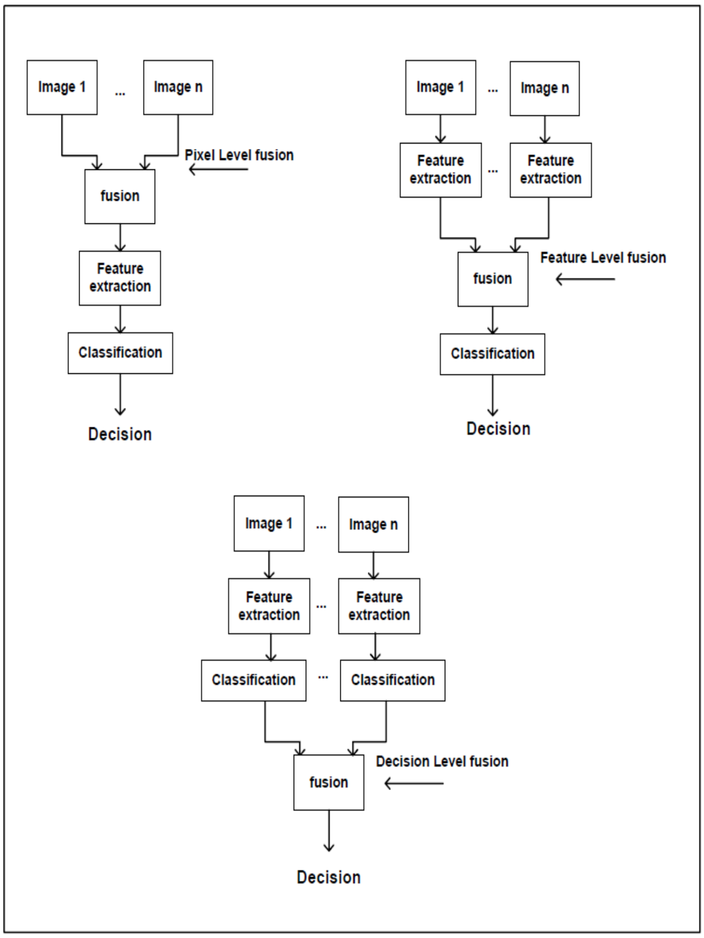

Fig.1. Levels of Image Fusion

Pan sharpening is a pixel level combination technique used to increase the spatial resolution of the multispectral image. Pan sharpening techniques raise the spatial resolution while simultaneously preserving the

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spectral information in the multispectral data [1]. Pan sharpening is also known as resolution merge, image integration, and multisensor data synthesis. Some of the uses of pan-sharpening include improving geometric correction, enhancing certain features not observable in either of the single data by yourself, change detection using temporal data sets, and enhancing classification.

II. Literature survey

Pohl et al. provided a complete review of the dissimilar methods used for pan-sharpening and the need to assess the excellence of the fused image[1]. The Intensity-Hue- Saturation transform based sharpening, principal component analysis based sharpening, Brovey sharpening, regression model built sharpening, and wavelet transform based sharpening are some of the usually used methods.

Carper et al. used the IHS transformation method for performing pan-sharpening[2]. The IHS sharpening was useful to SPOT multispectral and panchromatic image. The sharpened image was then used to make maps.

Chavez et al. used the principal component analysis (PCA) based method for merging multiresolution multispectral data [3]. The algorithm was used to sharpen LANDSAT multispectral image and SPOT panchromatic image. The sharpening outcomes were associated to the IHS sharpening and a high pass filter sharpening approach. The Brovey transform is built on multiplying ratio images with the panchromatic image. The Brovey sharpened images have very high contrast [1].

Zhang presented a synthetic variable ratio method, which used regression analysis in the middle of the multispectral and panchromatic image to compute certain parameters [4]. The method was realistic to sharpen LANDSAT multispectral image using SPOT panchromatic data.

Nunez et al. presented an image fusion method using additive wavelet decomposition for inclusion a SPOT panchromatic image with LANDSAT TM multispectral image [5]. The 'a trous' algorithm was used to compute the wavelet coefficients. The coefficients were then fused using an additive model to produce the sharpened image.

King et al. introduced a wavelet based pan-sharpening algorithm for LANDSAT 7 images [6]. The multispectral images were improved using the Intensity-Hue-Saturation (IHS) transform and discrete wavelet transform (DWT). The biorthogonal DWT was used to calculate the wavelet coefficients. The wavelet coefficients were then fused with the intensity component of the multispectral image to create the sharpened image.

Chipman et al. offered a wavelet transform based image fusion algorithm [7]. They intended a fusion system that accentuates different frequency regions from different images to produce the output fused image. A variety of mixture rules were tested with in the wavelet domain. They used simple mixture rules like be an average of the wavelet coefficients or keep in mind either the maximum or minimum coefficient in a sure frequency region.

Tseng et al. used a mixture of PCA and wavelet based sharpening methods [8]. The MS image bands were distorted into the PCA domain. The first principal component and the panchromatic image were merged using a wavelet- based method very similar to the method used by Nunez et al. The merged first principal component was made using a selection rule, which selects the maximum absolute value in the wavelet domain. The lasting principal components are resampled and the inverse PCA transform is applied to get back to the image domain.

Ouarab et al. used different mixture models in the wavelet domain [9]. They use a linear model to combine the wavelet planes of MS and panchromatic image. They also use a hybrid model wherein the panchromatic image is strained to have the same mean and variance of the MS image bands previously sharpening is realistic. The method was useful to perfect LANDAT TM multispectral bands using a SPOT panchromatic band.

III. Block Diagram

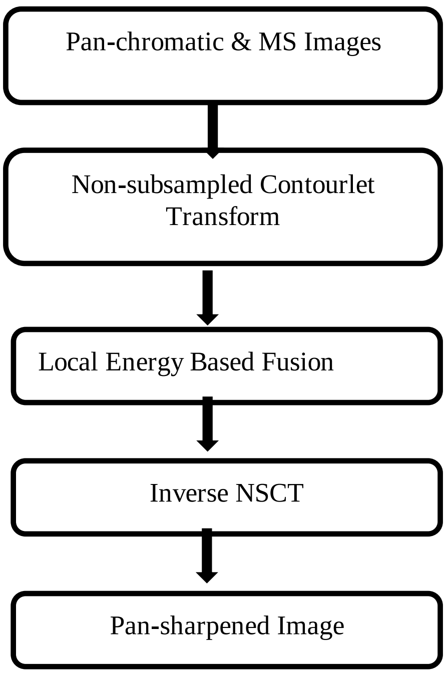

Fig.2. Block diagram of the proposed system

Into the block diagram flow of the work is given into one after one, input images(PAN and MS) are taken, as input images(PAN and MS) has noise we have to pre-process, the given input image for reducing noise and to enhance the contrast. Pre-processing has been done by using Median filter, pre-processing may include registration, resampling and histogram matching of the MS and PAN images then enhancing images(PAN and MS) by NSC transform. The NSCT is a fully shift-invariant, multi-scale, and multi-direction expansion that has better directional frequency localization and a fast implementation. The output of NSCT contains low as well as high frequency which can be fused through energy base fusion method and also used up-sampling for obtaining a higher-resolution version of the image. The fused image formed will be high in quality; it signifies every object from both images very accurately and it can also provide more detailed information about the scene. Pan-sharpened image will get using inverse NSC transform.

IV. WAVELET BASED SHARPENING

The wavelet transform is a mathematical tool widely used in image analysis and image fusion. The wavelet transform is generally used in pan-sharpening due to its properties such as multiresolution, localization, critical sampling, and inadequate directionality (horizontal, vertical, and diagonal directions) [5]. However, it fails to capture the smoothness along the contours [1]. CT seems to overcome this drawback [6]. In fact, CT is a multiresolution transform that provides an effective directional representation and takes into consideration wavelet properties. Thus, CT has been used for image fusion and pan-sharpening in [1] and [5]. The non-subsampled Contourlet transform (NSCT) is a shift-invariant version of CT.

A] NSCT decomposition

A number of image processing tasks are efficiently carried out in a domain other than the pixel domain, frequently by means of an invertible linear transformation. For example, image compression and de-noising are efficiently done in the wavelet transform domain. A good transform or representation would capture the essence of a given signal or class of signals with one some basis elements. The set of basic functions completely characterizes the transform and this set can be disused or not, depending on whether the basic functions are linear dependent. By allowing redundancy, it is possible to develop the set of basic functions so that the representation is more efficient in capturing some signal behaviour. Applications such as edge detection, contour detection, de-noising, and image restoration can greatly benefit from redundant representations.

CT can be separated into two stages, including the Laplacian Pyramid (LP) and Directional Filter Bank (DFB), and offers an effective directional multi-resolution image representation. Among them, LP is first used to capture the point singularities, and then tracked by DFB to link the singular point into linear structures. LP is employed to decompose the original images into low frequency and high frequency sub-imageries, and then the DFB divides the high frequency sub bands into directional sub bands. A contourlet decomposed schematic diagram is shown in Fig.3.

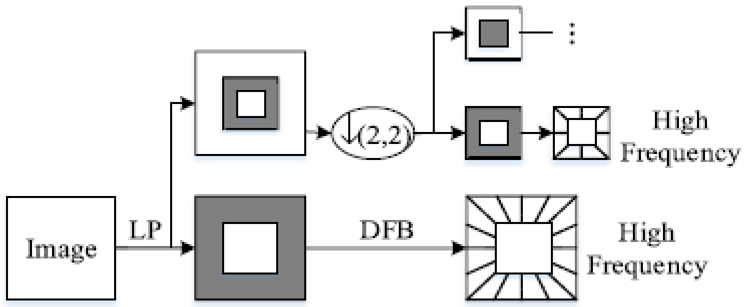

Fig.3. Contourlet decomposed schematic diagram

In the realization of the CT, the decomposition and construction filters of LP are separable bi-orthogonal filters with bandwidth greater than $\pi/2$. According to the sampling theorem, the pseudo-Gibbs phenomena would appear in low- and high-frequency sub-images in LP domain. Directional sub bands which come from the high frequency sub-images by DFB filtering would also look the pseudo-Gibbs phenomena. These phenomena would weaken the directional selectivity of the CT based method to some extent. To resolve this problem, A. L. Cunha *et al.*proposed NSCT based on the theory of CT. NSCT gets the advantage of CT, improves directional selectivity and shift-invariance, and effectively overcomes the pseudo-Gibbs phenomena.

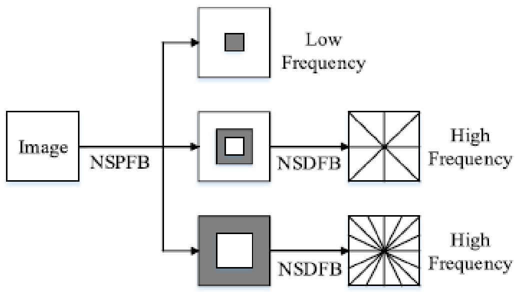

Fig.4. Contourlet decomposed schematic diagram

NSCT is based on Non-sub sampled Pyramid Filter Banks (NSPFB) and Non-sub sampled Directional Filter Banks (NSDFB). Fig.4 gives the non-sub sampled contourlet decomposition framework with k = 2 levels. The NSPFB ensures the multi-scale performance by making use of a two-channel non-sub sampled filter bank, and one low frequency sub-image and one high frequency sub-image can be formed at each decomposition level. The succeeding decomposition levels of Non-sub sampled Pyramid (NSP) are passed out to decompose the low frequency component existing iteratively to capture the line or plane singularities in the image. As a result, NSP can obtain k+1 sub-images, as well as one low and k high frequency sub-images. These sub-images have the similar size as the source images. The NSDFB is two-channel non-sub sampled filter banks constructed by eliminating the down-samplers and up-samplers and joining the directional fan filter banks in the DFB. NSDFB allows the direction decomposition with l levels in each high frequency sub-images from NSPFB, and then produces 2l directional sub-images with the similar size as the source images. Thus, the NSDFB provides the NSCT

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the multi-direction performance and offers extra exact directional detail information to get more accurate results. Therefore, NSCT leads to better frequency selectivity and has an important property of the shift-invariance on account of non-sub sampled operation. The size of changed sub-images decomposed by NSCT is identical, so it is easy to find the connection among sub-images of different images, which is useful to design fusion rules. Additionally, NSCT-based image fusion can effectively decrease the impacts of mis-registration on the results. Therefore, NSCT is additional suitable for image fusion.

B] The Non-sub sampled Pyramid (NSP)

The multi-scale property of the NSCT is a shift invariant filtering structure that achieves a sub band decomposition alike to that of the Laplacian pyramid. Our solution is obtained by using two-channel non- sub sampled 2-D filter banks. The proposed non-sub sampled pyramid (NSP) decomposition with J = 3 stages. Such expansion is conceptually similar to the 1-D non-sub sampled wavelet transform computed with the atrous algorithm. The filters for subsequent stages are found by up sampling the filters of the first stage. This gives the multi-scale property without the need for additional filter design. The suggested structure is thus different from the separable non-sub sampled wavelet transform (NSWT). In specific, one band pass image is created at each stage resulting in J + 1 redundancy. By contrast, the divisible NSWT creates three directional images at each stage resulting in 3J + 1 redundancy. The NSFB is built from a given low pass filter H0(z). One then sets H1(z) = 1 − H0(z), and G0(z) = G1(z) = 1. This perfect reconstruction system can be seen as a specific case of our more general structure. The advantage of our construction is that it is less preventive and as a result, better filters can be obtained.

C] Non-sub sampled Directional Filter Bank (NSDFB)

The directional filter bank of Bamberger and Smith is created by combining disapprovingly-sampled two-channel fan filter banks and resampling operations. The outcome is a tree-structured filter bank that splitting the frequency plane in the directional slices. The number of channels is L = 2l, where l is the number of steps in the tree structure. Using multirate identities, the tree-structured DFB can be put into the corresponding form. It is clear from the above that the DFB is not shift-invariant. A shift-invariant directional extension is obtained with a non-sub sampled DFB (NSDFB). The NSDFB is built by eliminating the down samplers and up samplers. This is equivalent to switching off the down samplers in each two-channel filter bank in the DFB tree structure and up sampling the filters consequently. This outcomes in a tree composed of two-channel non-sub sampled filter banks.

D] Combining the NSP and NSDFB in the NSCT

The NSCT is made by joining the NSP and the NSDFB. In constructing the non-sub sampled contourlet transform, care must be taken when put on the directional filters to the coarser scales of the pyramid. Due to the tree-structure nature of the NSDFB, the directional reply at the lower and upper frequencies suffers from aliasing which can be a problem in the upper stages of the pyramid. The pass band region of the directional filter is labeled as “Good” or “Bad”. Thus we see that for rougher scales, the high pass channel in effect is filtered with the bad portion of the directional filter pass band. This results in simple aliasing and in some experiential cases a considerable loss of directional resolution.

- With no up sampling, the high pass at higher scales will be filtered by the portion of the directional filter that has “bad” response.
- Up sampling ensures that filtering is done in the “good” region.

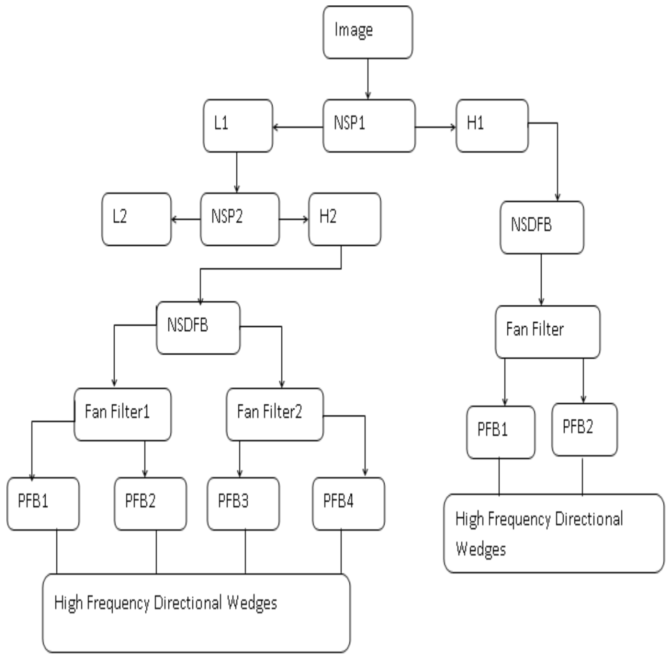

Fig.5 Decomposition Flow.

NSCT decomposition is to calculate the multi scale and different direction components of the discrete images. It involves the two steps such as non-sub sampled pyramid (NSP) and non-sub-sampled directional filter bank (NSDFB) to extract the texture, contours and complete coefficients. NSP decomposes the image into low and high frequency sub bands at each decomposition level and it produces n+1 sub images if decomposition level is n.

V. ALGORITHM

Pan-sharpening Method is showed as defined by the following algorithm steps given,

1. Each original MS band is decomposed, using NSCT, in coarse level and one fine level, whereas the Pan Image is decomposed into one coarse level and three fine levels.

2. The found MS coefficients are then up sampled using the bi-linear interpolation algorithm.
3. The coarse level of the Pan-sharpened MS band is the up sampled coarse level of the MS band.
4. Fine levels 2 and 3 of the Pan-sharpened MS band are set to fine levels 2 and 3 of the Pan Image.
5. Fine level 1 of the Pan-sharpened MS band is gained by merging the coefficients of the same level obtained from both the MS band and the Pan Image. The Fusion rule uses the local energy (LE) of each coefficients are calculated.
6. After the up sampling method a local edge preserving filter (LEP) is used to get high spatial and spectral qualities.
7. Finally inverse NSCT is obtained Pan-sharpened Image.

The fusion rule uses the local energy, to calculate LE given by the formula.

$$LE(x,y)=\sum_{i=-M}^{M}\sum_{j=-N}^{N}\left(Fine\_level\_coeff(x+i,y+j)\right)^2.$$

To map MS coefficients and pan coefficients we use the formula.

$$Fused\_fine\_level\_coeff(x,y) = \begin{cases} MS\_fine\_level\_coeff(x,y), & \text{if } LE_{MS}(x,y) \geq LE_{Pan}(x,y) \\ Pan\_fine\_level\_coeff(x,y), & \text{otherwise.} \end{cases}$$

VI. DISCUSSION & CONCLUSION

In this paper, the NSCT based pan-sharpening method in its standard form is considered. The pan-sharpening using NSC Transform is the powerful technique for satellite multispectral image enhancement. It involves two different approaches that are, NSCT with dissimilar levels of decomposition and NSCT with up sampling based pixel level fusion. NSCT is very capable in representing the directional information and capturing intrinsic geometrical structures of the objects. In this type, Local energy based fusion approach was utilized. Here, the satellite images will be enhanced with high spectral and special resolution.

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