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Fusion of Satellite Images in Transform Domain

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Unique—Image fusion in light of the wavelet and fourier trans-form comes about rich multispectral points of interest yet gives less spatial subtle elements from source images. Wavelet transform performs well at straight highlights yet not at non-direct discontinuities since Wavelets don't utilize the geometric properties of structures. Curvelet transforms defeat such troubles in include rep-resentation. A novel Image fusion rule by means of high pass balance utilizing Local Magnitude Ratio (LMR) in Fast Discrete Curvelet Transforms domain (FDCT) and Discrete wavelet transform (DWT) is characterized. Indian Remote Sensing Geo satellite images are utilized for MS and Pan images. This fusion rule creates HR multispectral image with high spatial resolution. This technique is contrasted and wavelet, Principal Component Analysis (PCA), Fast Discrete Curvelet Transforms domain fusion strategies. Master postured technique spatially performs alternate strategies and results rich multispectral information.

Keywords-Image Fusion, Discrete Wavelet Transforms, Fast

Discrete Curvelet Transforms, Principal Component Analysis

and Guided Filtering.

I. Presentation

The term image fusion implies when all is said in done a way to deal with extraction of information in a few images procured in a few domains. The objective of image fusion is to join correlative multitemporal, multisensory, and/or multiview information into one new image containing information the nature of image can't be accomplished with single image. The term quality, its significance and estimation rely upon the specific application.

Image fusion joins the different images to make a combined image containing high unearthly, radiometric and spatial resolutions[1]. In remote detecting, image fusion is important procedure for use of multispectral, multisensor at var-ious resolution parts of earth watching satellites. Spatial resolution assumes an indispensable part to outline the items in the remote detecting image. It is anything but difficult to contrast the highlights and high spatial resolution image with multispectral information than the single high resolution panchromatic image. Image fusion improves the spatial, unearthly and radiometric resolu-tions of images. Wavelet and Fast Fourier transform based image fusion techniques hold better unearthly qualities however speak to extremely poor spatial points of interest in combined image.

Sparse portrayal of signs is as of now possible utilizing an extensive variety of Greedy systems including Match-ing Pursuit, Orthogonal Matching Pursuit. These methods

are used to address movements with minimal number of non-zero coefficients.[PCA] Principal Component Analysis is fit best in class picture blend approaches similarly as visual survey and quantitative appraisal estimations [2]. This mix is finished by consolidating the primary portions of pictures to be merged. PCA is one of the remarkable space blend approaches. DWT is one of the change zone mix approaches. In DWT cost of handling is high and takes long weight time. Both PCA and Sparse blend have specific positive conditions and hin-drances. The primary weakness of Pixel level strategy is this procedure does not offer assurance to have an unmistakable items from the arrangement of images and Pixel level technique are influenced by obscuring impact which is influence on the image differentiate , PCA is a system which transforms number of connected variable into the quantity of uncorrelated factors, consequently this property can be utilized as a part of image fusion But spatial domain fusion may create phantom twisting and debasement. In DWT technique melded image have a less spatial resolution. Be that as it may, in the joined technique for PCA and DWT strategy is unpredictable in fusion calculation. Required great fusion system for better outcome

[3]. At last Combination of Pixel Energy Fusion rule holds Complexity of strategy increments. Consequently Curvelet transforms hold rich multispectral points of interest contrasted with different techniques.

Different Image Fusion strategies have been proposed to lessen the obscuring impacts. Image fusion advances the nature of image by killing the commotion and the obscure of the image. Image fusion have three unique levels i.e. pixel, choice and highlight. Its procedures can be comprehensively grouped into two that is Transform domain fusion and extraordinary domain fusion. Brovery technique, Averaging, PCA, based strategies are unique domain strategies. Be that as it may, uncommon domain strategies comes about unique mutilation in the intertwined image. This issue can be effectively settled by domain transform approach. The multi-resolution analysis has turned into an extremely helpful instrument for investigating images.

II. RELATED WORK

The goal of this work is to build up a system, which comes about better attributes of both otherworldly and spa-tial characteristics of source images. Discrete Wavelet transforms won't speak to the bended protests as in HR Pan image. Curvelet transforms defeats the mutilations of wavelet. Over a period, curvelet transforms are advanced in two ages,

for example, first era curvelet transforms and second era curvelet transforms named as Fast Discrete Curvelet trans-forms (FDCT).

The first era Curvelet transforms computational com-plexity is more to figure the curvelet coefficients . To over-come these anomalies [4] Emmanuel J.Candes created FDCT speaks to direct edges and bends precisely than any logical numerical transforms.

DWT is wavelet transform for which wavelets are carefully inspected. The primary favorable position of this is it catches both area and recurrence information in the meantime. Here the approach utilized is Haar wavelets. This is utilized to combine up input informative qualities, putting away the distinction coefficients and passing the aggregate. This procedure is rehashed recursively, blending up the total to give the following scale coefficients, which results to 2n-1 contrasts and a last total [5].

Ultimately the yield images of both DWT and FDCT are coordinated to get a last yield image which has preferred phantom and spatial resolutions over some other transformations to which thought about.

III. PROPOSED BLOCK DIAGRAM A. Preprocessing

Image pre-handling is the tasks on images at the low level of deliberation. These tasks don't build image information content however they diminish it if entropy parameter is an information measure as appeared in fig. 1. The principle point of pre-handling is a change of the image information that smothers mutilations and expands some image highlights pertinent for additionally preparing and analysis assignment. Image pre-handling utilizes the redundancies in images. The mutilated pixel can be wipe out from the image, it can be reestablished as a normal benefit of neighboring pixels. Image pre-preparing systems can be arranged by the extent of the pixel that is utilized for the figuring of another pixel brilliance. the accompanying advances are included as given by [6].

Image cropping and filtering

Histogram Equalization and Intensity adjustment Brightness thresholding

Clearing areas of Binary image Detecting edges

B. Discrete Wavelet Transform[DWT]

Wavelet transform is one of the important tool used for image processing and signal processing techniques. Wavelet transforms and its application in the compression and cleaning of the images.

Basically wavelets transforms are classified into two types, first is easily reversible, where the original signal is recovered after its transformation method. It is used in image compression and image cleaning. Second type is used for the analysis of the signal and sensor measurement fault detection. Here the modified form of the original signal is not required and the wavelet transform is not inverted back [7].

The DWT of a signal is calculated by equation1 passing

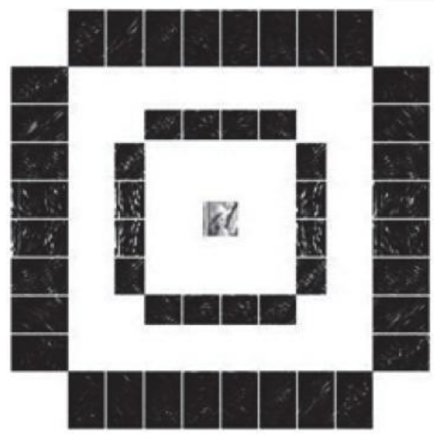

Fig. 3. illustrates the Curvelet coefficents at scale j=0 and at j=1, 2. in multiple Directions

it through a series of filters. Initially samples are passed through a low pass filter with impulse response resulting in a convolution of the two.

$$y[n] = (x * g)[n] = \sum_{k=-\infty}^{\infty} x[k]g[n-k] \qquad (1)$$

1) Fast Discrete Curvelet Transform: The low frequency (coarse scale) coefficients are shown at the center of the display in fig. 2. The cartesian concentric corona show the different coefficients at different intervals. The outer most corona corresponds to high frequencies. There are 4 strips associated to each corona in South, north, east and west direction, these are further subdivided in angular panels[8]. Each panel represents coefficients at a particular scale and suggested orientation by the position of the panel.

In a directional sub-band, high curvelet coefficients of LR multispectral image and HR Pan image represent sharp local feature [9]. In this paper, we intialize a Local Magnitude Ratio (LMR) to implement high frequency details of the local image feature into the fused image. LMR is as follows.

Suppose cj,l(M) cj,l(P) are the sub-band curvelet coefficients at scale j in a direction l of the multispectral band M and pan image P at larger frequencies respectively.

LM Rj; l(x; y) = jcj; l(M(x; y))j jcj; l(P (x; y))j (2)

Where LM Rj; l(x; y) is the sub-band curvelet coefficients at scale j in direction l at location (x; y). If LM Rj; l(x; y) 1 then cj; l(P (x; y)) indicates good local feature of image. If LM Rj; l(x; y) 1 then cj; l(M(x; y)) indicates the good local feature[10]. Fusion rule to inject high spatial details from High Resolution pan image into LR multispectral image bands is initialized using Local Magnitude Ratio of curvelet coefficients in the directional high frequency sub-bands.

IV. IMAGE FUSION USING FDCT

The following is the specific operational procedure for the proposed curvelet-based image fusion approach., Landsat

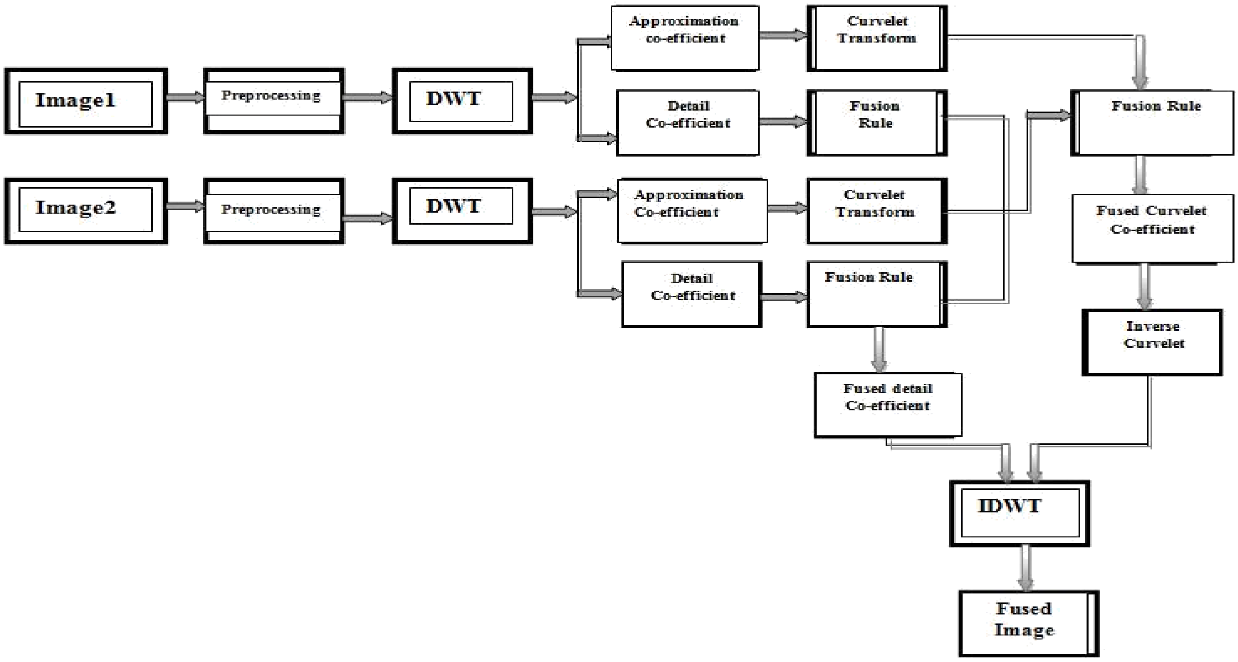

Fig. 1. Block Diagram of image fusion with FDCT

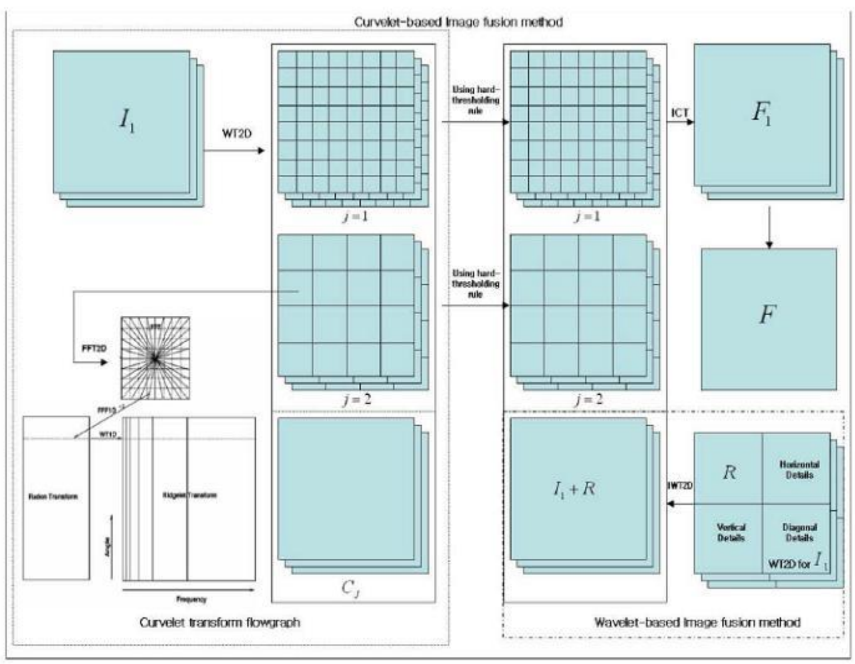

Fig. 2. image fusion using FDCT and DWT

ETM+images are utilized as an example and shown in fig3 in order to illustrate the method. 1. The original multispectral images are geometrically and Landsat ET M panchromatic preprocessed to each other.

2. Three new panchromatic images+ Landsat Enhanced The-matic Mapper ET M + I1; I2andI3 are produced. The his-tograms of these images are specified according to the his-tograms of the multispectral images RGB colors respectively.

3. Using the wavelet based image fusion method, we obtain fused images I1 + R; I2 + GandI3 + B, respectively.

4. I1, I2 and I3, which are taken from step2, are discretized into J + 1 sub bands, respectively, by applying sub band filtering algorithm. Every decomposed singular image includes CJ which was smooth version of the original image, and wj ,

TABLE I
DIFFERENT QUALITY METRICS FOR DWT EXPERIMENT

Band-1	Band-2	Band-3
mse = 97.1448	mse =69.0244	mse = 70.3510
psnr = 8.3824	psnr = 11.3507	psnr = 11.1854
entropy =-1.8105e+08	entropy =-1.7564e+08	entropy= -1.7183e+08
cross correlation= 3.5061e+09	cross correlation=3.2302e+09	cross correlation= 3.0369e+09
average gradient val = 9.2723	average gradient val =,9.2699	average gradient val = 9.2072
uiqi = 1.0308e-11	uiqi = -1.2800e-12	uiqi = 5.1527e-12
Blur = 0.4490	Blur = 0.4490	Blur = 0.4490

which indicates the details of I at scale 2 j as shown in fig 3.

5. Every coefficient CJ is replaced by a fused image obtained from 3). For example, (CJ for I1) is replaced by coefficient (I1 + R).

6. Important transformation called ridgelet transform is then applied to each block in the decomposed I1, I2 and I3, respectively.

7. Curvelet Transformation coefficients (or ridgelet coeffi-cients) are modified using hard-thresholding rule in order to enrich and to enhance the edges in the fused image.

8.Another crucial step is applying Inverse curvelet transforms (ICT) are carried out for I1, I2 and I3.Three new images F1, F2 and F3 are then obtained, which reed the spectral information of the original multispectral images R, G and B, and also the spatial information of the panchromatic image.

9. F1, F2 and F3 are integrated into a single fused informative image F. In this approach, the obtained optimum fused image of richer information in the spectral and spatial domains simul-taneously. hence, the curvelets based image fusion technique is very useful and efficient for image fusion[11]. Satellite images can be downloaded from the website after registration-

http://bhuvan.nrsc.gov.in/bhuvan_links:php

V. EXPERIMENTAL RESULTS

Satellite images are used for panchromatic and multi-spectral images. For clear visualization, subset images of the fused images of different methodsFigure(4-8) are ob-

Fig. 4. Panchromatic input image

Fig. 5. Multispectral input Image

tained by various methods and analyzed with respect to
PSNR,MSE,Entropy,Cross correlation and Blur Metric[14] ,
the amount of image blur is characterized by the average extent
of edges in the image, or more specifically the average extent
of the slope’s spread of an edge in the opposing gradients’
directions. The effectiveness of such method is validated using
subjective tests on blurred images, including JPEG-2000 coded
images. Figure 4 is the original HR Pan image and Figure 5
is the sampled Lowresolution multispectral image. Figure 6
is the HR multispectral image obtained by fusion rule based

on FDCT. Figure 7 is the fused image got after applying
combined FDCT-DWT transforms. Quality of the fused images
are evaluated with both spectral quality measures and spatial
quality measures.

Comparative analysis of satellite image fusion by different

method by using Different Quality Metrics

Result Image

Fig. 6. Fused image using FDCT

A. Image Fusion by Guided Filtering

Guided filter is used to decompose the source images into

base layer and detail layer.
The base layer is computed by applying Gaussian and
laplacian pyramidal approach to the weight map.
A fused base layer and detail layer are computed from
the weight map of the base layer and decomposed source

TABLE II
DIFFERENT QUALITY METRICS FOR FDCT EXPERIMENT

Band-1	Band-2	Band-3
mse =10.7668	mse =9.3522	mse = 9.1610
psnr = 27.4891	psnr = 28.7125	psnr = 28.8919
entropy =-2.8814e+08	entropy =-1.8927e+08	entropy= -2.1200e+08
cross correlation= 6.9330e+09	cross correlation=3.9596e+09	cross correlation= 4.6313e+09
average gradient val =8.5236	average gradient val =10.0647	average gradient val = 9.7056
uiqi = 8.9758e-11	uiqi = 5.0483e-12	uiqi = 5.1527e-12
Blur = 0.3419	Blur = 0.3419	Blur = 0.3419

Image fusion by guided filtering

Fig. 8. Fused image using combined FDCT-DWT

image output is obtained by detail layer respectively and output for guided filtering is shown in fig8.

Image Fusion by Fast Discrete Curvelet Transform(FDCT)

Curvelet transform is more useful for the analysis of images having curved shape edges.

Spatial resolution ratio between HR Pan image and LR multispectral image is 2. Input source images size must be power of 2 for the coherent multi resolution decom-position in FDCT domain. To obtain High resolution multispectral image, high frequency informative details are injected into each LR multispectral band in FDCT domain.

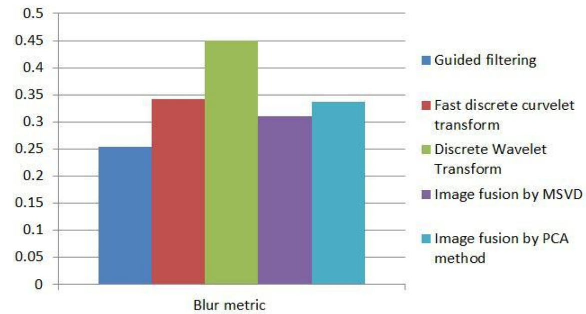

Fig. 9. Blur Metric Analysis for Fusion Techniques

B. Image Fusion by Discrete Wavelet Transform

It provides better signal to noise ratio than pixel based approach.

output image contained both high quality spectral content with high spatial resolution .

C. Image Fusion by Multi resolution singular value decom-position(MSVD)

MSVD is very similar to wavelets transform, where signal is filtered separately by high pass and low pass finite impulse response(FIR) filters and the output of each filter is decimated by the factor of two to get first level of decomposition.

The decimated low pass filtered output is filtered sepa-rately followed by decimation by a factor of two provides second level of decomposition.

VI. CONCLUSION

The fusion method is based on the improved features of FDCT and DWT. Two fusion rules are defined, fusion rule 1 is for curvelet coefficients at lower frequencies and fusion rule 2 in FDCT is for the curvelet transform coefficients at very higher frequencies. Fusion rule 1 substitute scale coefficients of LR multispectral bands into the scale coef-ficients of HR Panchromatic image. Fusion rule 2 is based on the high pass modulation using Local Magnitude Ratio of the curvelet transform coefficients for every scale and orientation. Bigger curvelet coefficients of LR multispectral and HR Panchromatic image represent sharpened local feature. LMR directs the injection of high frequency details of the local image feature in High Resolution Panchromatic image into fused informative image. For experimental study of this method Indian Remote Sensing satellite images are used for Panchromatic and Multispectral images. This fusion rule generates HR multispectral image at 2.5m spatial resolution with high spectral information. This method is compared with Wavelet, PCA fusion methods. Proposed method outperforms the other methods and retains rich multispectral details and hence by considering table 1 and 2 transform domain is more efficient for multispectral and panchromatic images.

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