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Review Article

HYPERSPECTRAL AND MULTISPECTRAL IMAGE FUSION USING NSCT AND FDCT METHODS

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Abstract:
Image fusion plays an important role in computer vision, medical imaging, robotics, remote sensing and satellite imagery. Image fusion is a method or a process in which it produce all relevant information in a single image by combining two or more input images. The final image or final output contains more information than a single image. Hyperspectral image known as HIS and Multispectral image fusion known as MSI are used in wide array of application although it originally developed for geology and mining because of high spectral-resolution but it has low spatial-resolution. Non-Subsampled Contour let Transform known as NSCT. Hyperspectral and multispectral Image Fusion using NSCT and FDCT methods are used in this paper and it can be used in various fields like medical imaging, Satellite images, space research and remote sensing.

Keywords:- Hyperspectral image (HSI), Multispectral image (MSI), Non-Subsampled Contour let Transform(NSCT), Fast discrete curvelet transform(FDCT),

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INTRODUCTION

Image fusion plays a great role in many areas like medical field, military application, wireless systems and satellite imagery. The Image fusion is a method of merging two or more images to a single image. The basic requirements of the Image fusion is the resulted single image must contain all the important information from the initial images. The combined picture shows all the information accessible in the given picture. The Image combination assumes an incredible job in our everyday life, a portion of the utilization of picture combinations are in the restorative field we use picture combination to analysis and location of measured related issue and conditions. Furthermore, in the military field, we use picture combination for observation purposes to recognize the adversary interruptions. With respect to remote structures, the data encounters transmission stage, channel and gatherer stages where it encounters various sorts of clamour and its possessions. For example, in the transmission sort out, during the testing and quantization, the image is impacted by what is known as partner and quantization upheaval which is caused due to looking at botches. Right when it sent for the encoding method, the image is impacted by certain commotion. Exactly when the data is transmitted through a channel, the image is affected which changes the characteristics of the image enormous..

Another significant confinement is that of the brightening is caused because of short unique range that outcome from the kind of picture obtaining gadget. Numerous strategies for image improvement considering the spatial area is master presented, in any case, with regards to picture combination, the extent of picture upgrade stays to be managed. Picture combination strategies considering the noise factor and the light conditions are constrained which in any case has a more noteworthy extent of utilizations and centrality. Strategies for picture combination chiefly include transient based techniques which applies imaging procedures on a period series space.

Hyperspectral image known as HIS is used in wide array of application although it originally developed for geology and mining because of high spectral-resolution but it has low spatial-resolution. Multispectral image known as MSI has low spectral-resolution but it has High spatial-resolution. The fusion of HIS and MSI fusion is called HS-MS fusion. It has a many practical application in recent years, including cell phenotype analysis, biomass, crop species identification and mineralogy mapping. However the Hyperspectral image cannot have high spatial resolution and also high spectral resolution because of the limitation of the sensor hardware and signal of noise ratio. To actually also to obtain the high spectral resolution the multispectral Images are used in the process of fusion it is the best method. The image fusion is the process of combination of multiple images into a single image to obtain a high quality fused image.

Strategies for picture combination for the most part include transient based strategies which applies imaging procedures on a time series methods or models. The Non-Subsampled Contour let Transform known as NSCT and Fast discrete curvelet transform known as FDCT is used in the HS-MS fusion. It is known that there are many methods to get the image fusion but we are using Non-Subsampled Contour let Transform and Fast-discrete curvelet transform are implemented considering the aspects of noise factors of the images and image illumination. The comparative methods are going to be performed in the following sections.

The method will be illustrated in this paper as we going to mention in the first section about introduction which signifies the importance and the limitations of image fusion methods. The second section deals with the related works, the third section deals with the proposed system. The fourth section deals with the results and discussions followed by the fifth section references.

RELATED WORKS

Qi Wei et al [1] presented a based approach in combining the multispectral and hyper spectral images. They intended to limit the objective capacity. When contrasted and some other four best in class combination techniques, the combination strategy they proposed have a littler ghostly bending and littler spatial error. The specific sparse prior was attributed for improvement.

S. Saranya sri et al [2] illustrated the multimodal combination structure utilizing the non-sub-sampled Contourlet transform in the Hyper Spectral and Multi Spectral Images. The initial segment uses a NSCT space for mix and after that subsequent stage to improve the distinction of the definite components by utilizing Guided picture. A quantitative assessment of intertwined pictures is finished using gave blend estimations. A soft computing algorithm is used to replace the normal fusion rule in the fusion system. Fused image using NSCT and guided filter is very effective and it yields excellent clarity in the fused images and sharpness it is improved than the multi-resolution transform based fusion,

K. P. Indira et al [3] proposed a method to fuse the medical images taken from the Positron Emission Tomography or Computed Tomography taken from the tumor boundaries because they are not easy to discern. The medical fusion images are based on Discrete Wavelet Transform it is used on medical images. For quantitative and qualitative the results the contrast method is better than choose max method. By applying the different fusion rules the choose contrast, max based fusion rule for Discrete Wavelet Transform are suited for the Positron Emission Tomography, Computed Tomography based real time images.

Surabhi Agarwal et al [4] introduced a new Brovey Transform technique to enhance the application of the images fusion. The brovey transform or u can say as BT procedure is taken in the process of image fusion, it illustrates the PS or NS, MSE and Cross Correlation. Increase application effectiveness of image combining based on fusion, the noise ratio, Cross Correlation need to be augmented while the mean square error has to be reduced. The finalized image fusion processed by the Brovey Transform has yielded great performance when compared to other wavelet transform with regards to Peak signal or noise ratio, Mean Square Error and Cross Correlation

Shivanand R. Kollannavar [5] proposed a strategy for picture combination includes for the most part pre-handling, in the picture combination the DWT and FDCT strategies are taken. The PSNR, MAE , SSIM, SNR measures are taken all the while. The inclination and standard deviation techniques are taken. The FDCT based picture combination technique performed with high measures than the DWT based picture combination. The FDCT furnishes a higher exactness when contrasted and the DWT strategy. The assortment of uses extending from clinical diagnostics to satellite symbolism can be considered for this technique for picture combination. This system could be tried on continuous envisioning information.

Bhavana. V et al [6] proposed another combination technique known as Multi-Modality Medical Image Fusion utilizing Discrete Wavelet Transform, it is utilized for the combination of pictures which is taken from PET and MRI cerebrum pictures dependent on DWT known as discrete wavelet change. The final images will have less colour distortion and no losses in anatomical information

K. KoteswaraRao et al [7] proposed a fusion method is used in Multi-Modality Medical. It is done both fields to get a better result. The important bands in non-sub-sampled Contourlet transform is selected by the energy of decomposed bands in non-sub-sampled Contourlet transform. The ESOP values are taken in this spatial fusion and several medical images are used to get the resulted image.

Xuelong Li et al [8] have this limitation because of hardware. The image fusion is the method to get the resulted image in both high in spectral and spatial resolution. The band simulation method is used in the fusion of Hyperspectral and Multispectral Images. The Band simulation method using spectral un-mixing and it acquires high resolution image. It is based on linear least squares.

Anjali A et al [9] illustrates that in numerous significant imaging applications, in images display edges and discontinuities across bends. In natural symbolism, this happens at whatever point two organs or tissue structures meet. Particularly in picture combination the edge safeguarding is significant in acquiring the corresponding subtleties of the info image. As edge portrayal in curvelet change is better and wavelet change gives picture subtleties. The mix of wavelet and quick discrete curvelet change applied to clinical pictures may give better combination results helpful for analysis. This can be utilized to give the edge data obviously and speed of calculation will be high contrast with different techniques. The proposed technique might be valuable for scientists for additional exploration take a shot at image fusion.

METHODOLOGY

This section deals with the methods taken in the process of HS-MS fusion.

Fusion based on NSCT

Non-subsampled contour let Transform also known as NSCT. It is used in multi-directional, multi-resolution. The pyramid without sub-sampling known as known as NSDFB are the two stages comprises in it. non sub-sampled two channel filter bank is the first stage in this process which provides a multi-scale property.

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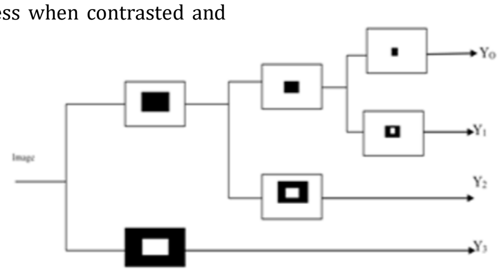


Figure1. NSP decomposition in three stages

In NSP to bring the uniqueness, N will be the no. of decomposition it will take. The sizes of the sub images and the source are same after decomposition. From figure 1 u can say that it has three stages of NSP so the values of N =3.

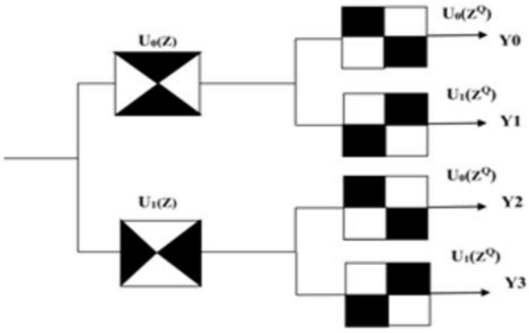


Figure2 .Four channel NSDFB

Because of that the Non sub sampled directional filter bank provides a multi directional ability which will give more decisive information about directionality.

$$E1(g,h) = \sum_{g-1}^{g+1}\sum_{h-1}^{h+1} A(g,h) \quad (1)$$

$$E2(g,h) = \sum_{g-1}^{g+1}\sum_{h-1}^{h+1} B(g,h) \quad (2)$$

The energy of each band is mathematically calculated using this formula. Where E is the energy of the band and where A and B are the two of the source images.

Fast Discrete Curvelet Transform

The Fast Discrete Curvelet Transform also known as FDCT. The real valued curvelet component is first transformed from the pre-processed images. Type wavelet is the probability for the finest level of the curvelet.The computerized execution of the original curvelet is progressively intricate and requires a progression of steps, for example, sub-band disintegration, smooth dividing, standardization, and Ridgelet investigation, and the decay of the curvelet pyramid likewise brings a tremendous measure of information excess. So Candes et al. proposed a snappy and straightforward curvelet change calculation, to be specific the second-generation curvelet.

The second-generation curvelet is totally unique in relation to the original. The original curvelet's development thought is to around treat the bend in each square as a straight line through enough little squares, and afterward utilize the local ridgelet to examine its attributes. The second-age curvelet and ridgelet hypothesis have no connection, and the usage procedure likewise doesn't have to utilize ridgelet. The main contrast between the two hypotheses lies in theory numerical significance, for example, tight help and system.

The discrete curvelet transform is

$$c(x,y,z) = \int \bar{f}(w)\overline{V_j}\,(S_{\theta 1}^{-P}\,\omega)e^{i(S_{\theta 1}^{-P}a,\omega)}d\omega \quad (3)$$

Since the shear block $S_{\theta 1}^{T}$ $(k_1 \times 2^{-j}, k_2 \times 2^{-j})$ is not a standard rectangle, in order to use the fast Fourier algorithm, the above equation could be rewritten as

$$c(x,y,z) = \int \bar{f}(S_{\theta 1}\omega)\overline{V_j}\,(\omega)e^{i(a,\omega)}d\omega \quad (4)$$

Then the FDCT is implemented by the warp algorithm using in local Fourier Transform.

The wrap around the origin is the core idea of the curvelet based on the Wrap algorithm. Any region is mapped to the affine region of the origin through the periodic technique. This mapping is a one-to-one correspondence. Specific steps are as follows:

Step 1: Obtaining $\bar{f}[m_1,m_2]$−n/2 ≤ m_1, m_2<m/2 through two-dimensional (2-D) FFT on f[it_1, it_2]∈L^2(R).

Step 2: Multiplying $\bar{f}[m_1,m_2]$ by parabolic window $\overline{U_{g,h}}(m_1,m_2)$ for each scale and angle parameter set (g,h) to localized $\bar{f}$.

Step 3: Localizing $\bar{f}$ by warping around the origin then getting $\overline{f'_{g,h}}[m_1,m_2] = W(\overline{V_{g,h}}\,\bar{f})[m_1,m_2]$

Step 4: Implementing 2-D IFFT to localized $\overline{f'_{g,h}}$ and finally obtaining the discrete curvelet coefficients $c^{D(e,g,h)}$.

PROPOSED FUSION FRAMEWORK

This part deals with HS-MS Image Fusion Using Non-Subsampled Contour let Transform and Fast Discrete Curvelet Transform Methods.

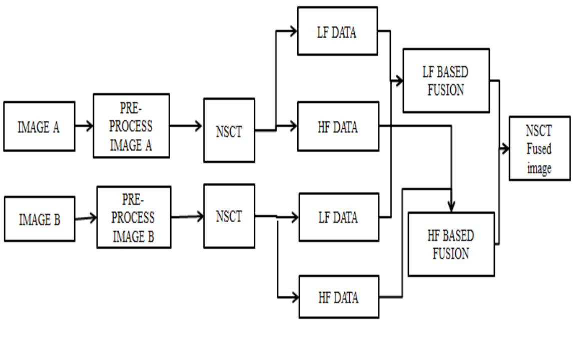


Figure3. Image fusion using NSCT

In the figure3 the image A and B are pre-processed, using Non-Subsampled Contour let Transform method the high frequency and low frequency data's are gotten. From the respective images the values are taken and processed through equation (1) and (2) and the energy of each band is calculated. And the NSCT fused images is calculated from energy based fusions.

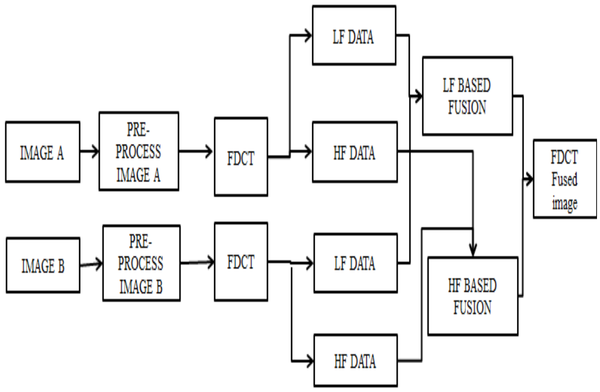


Figure4. Image fusion using FDCT

In the figure3 the image A and B are pre-processed, using Fast Discrete Curvelet Transform method the high frequency and low frequency data's are gotten. From the respective images the values are taken and processed through equation (3) and (4) and the energy of each band is calculated and FDCT fused image is calculated.

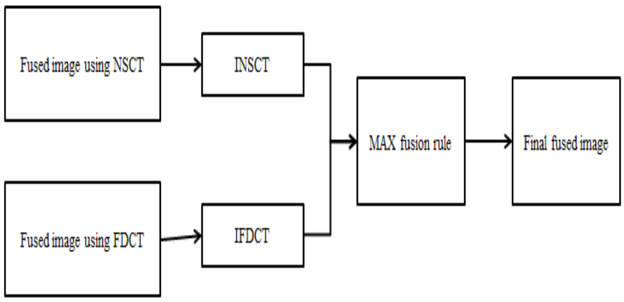


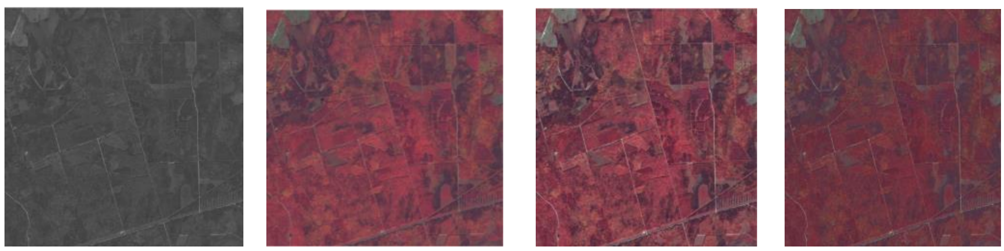
Figure5. Fusion of NSCT and FDCT

In the figure 5 the finalized fusion image is taking place. The fused image using Non-Subsampled Contour let Transform and from Fast Discrete Curvelet Transform methods are going through the inverse operation took place and then MAX fusion rule is applied to get the finalized fusion image.

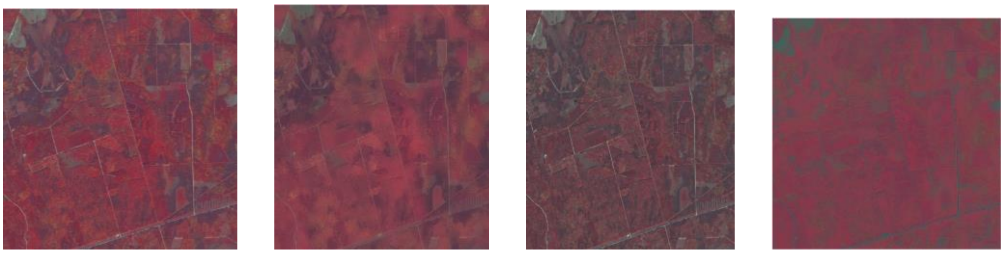
The Algorithm can be summarized as follows

1. Select from figure3 Input Image A for Hyperspectral Image method as I_{HS}^{N}, and select Input Image B for Multispectral Image method as I_{MS}^{N}.
2. Select from figure4 Input Image A for Hyperspectral Image method as I_{HS}^{F}, and select Input Image B for Multispectral Image method as I_{MS}^{F}.
3. Apply Pre-processing in $I_{HS}^{N}, I_{MS}^{N}, I_{HS}^{F} and\ I_{MS}^{F}$.
4. Images are Decomposed in the NSCT as Low frequency data I_{HSL}^{N}, I_{MSL}^{N} and high frequency data I_{HSH}^{N},I_{MSH}^{N} are collected.
5. To get the Energy based fusion on NSCT method the Equation (1) and (2) are used and we get E^{N1}, E^{N2}. And we get I^{N} the final fused image from NSCT method .
6. To get the final fused image from FDCT method the Equation (4) is used to get I^{F}.
7. The Inverse method is used on the NSCT energy based fusion value(I^{N}).and we get the inverse value (I^{iN}).
8. The Inverse method is used on the FDCT energy based fusion value(I^{F}.and we get the inverse value (I^{iF}.).
9. The Max fusion rule is applied on the both inverse values we got from NSCT and FDCT methods and we get the Finalized fusion image(I^{HSMS}).
10. The HS-MS fusion value(I^{HSMS}) is obtained by Non-Subsampled Contour let Transform and Fast Discrete Curvelet Transform methods.

RESULT AND DISCUSSIONS:
Landsat-7 ETM+ dataset



(a) (b) (c) (d)



(e) (f) (g) (h)

FIGURE 6. Landsat-7 ETM+ data fusion results. (a) PAN image. (b) MS image. (c) Proposed method. (d) Brovey method. (e) IHS method. (f) Guided method. (g) NSCT method. (h) PCA method.

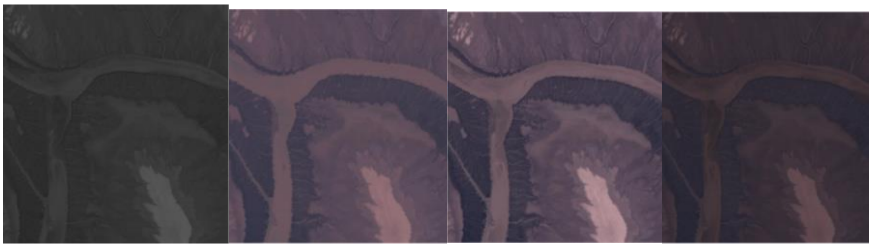
IKONOS data set

(a) (b) (c) (d)

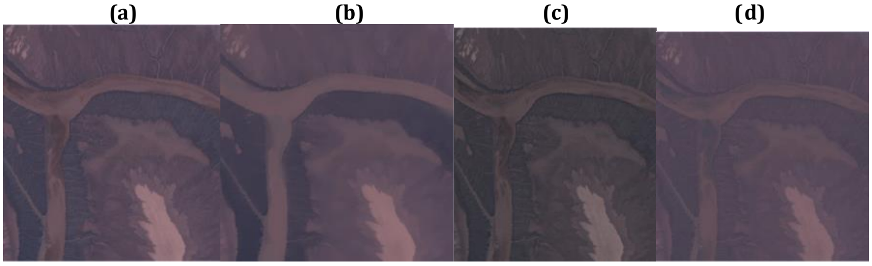
(e) (f) (g) (h)

FIGURE 7. IKONOS fusion results. (a) PAN image. (b) MS image. (c) Proposed method. (d) Brovey method. (e) IHS method. (f) Guided method. (g) NSCT method. (h) PCA method.

QuickBird



(a) (b) (c) (d)



(e) (f) (g) (h)

FIGURE 8. QuickBird data fusion results. (a) PAN image. (b) MS image. (c) Proposed method. (d) Brovey method. (e) IHS method. (f) Guided method. (g) NSCT method. (h) PCA method.

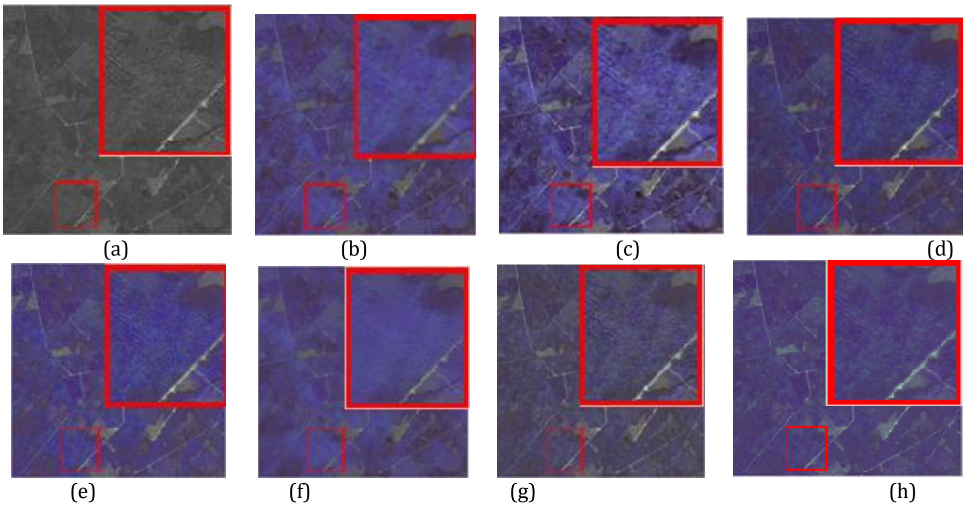


FIGURE 9. Zoomed Landsat-7 ETM+ data fusion results. (a) PAN image. (b) MS image. (c) Proposed method. (d) Brovey method. (e) IHS method. (f) Guided method. (g) NSCT method. (h) PCA method.

Correlation Coefficient:
The correlation coefficient is defined as measurement of the similarity between two images. Thus calculation of similarity between fused image and reference image is given by the following equation .

$$CC = \frac{\sum_{i=1}^{a}\sum_{j=1}^{b}[A(i,j)-\bar{B}][E(i,j)-\bar{E}]}{\sqrt{\{[\sum_{i=1}^{b}\sum_{j=1}^{a}B(i,j)-\bar{B}]^2\}\{[\sum_{i=1}^{b}\sum_{j=1}^{a}E(i,j)-\bar{E}]\}}} \quad (5)$$

Entropy:
The entropy is defined as measure of the image information content. The larger value obtained mean high information in fused image.

$$\text{Entropy} = -\sum_{0}^{255} E(i)\log 2\, E(i) \quad (6)$$

MSE:
The Mean Square Error (MSE) is used calculate the average error of the pixels in the images.

$$MSE = \frac{1}{M \times N}\sum_{c=0}^{N-1}\sum_{d=0}^{M-1}[A(c,d)-Z(c,d)]^2 \quad (7)$$

UIQI:
Universal Image Quality Index (UIQI) is defined by Wang and Bovik as follows

$$Q = \frac{\sigma CD}{\sigma C\sigma D}\cdot\frac{2nCnD}{(n_A)^2+(n_B)^2}\cdot\frac{2\sigma A\sigma B}{(\sigma_A)^2+(\sigma_B)^2}. \quad (8)$$

Where C and D are the images and variance of C and D image σ_C^2, σ_D^2 and n is the mean value.

TABLE 1. Objective quantitative evaluation of the full scale and degraded scale experimental results of Landsat-7 ETM+ data

Method	Brovey	HIS	Guided	NSCT	PCA	Proposed
CC	0.8633	0.8394	0.5724	0.9133	0.9331	**0.9462**
Entropy	6.2063	6.5024	5.9372	5.9236	6.1685	**6.7147**
MSE	0.6198	0.6451	0.6648	0.6408	0.6458	**0.6752**
UIQI	0.9025	0.8975	0.8552	0.9063	0.8945	**0.9298**

TABLE 2. Objective quantitative evaluation of the full scale and degraded scale experimental results of IKONOS data

Method	Brovey	HIS	Guided	NSCT	PCA	Proposed
CC	0.9616	0.9707	0.9725	0.9704	0.6973	**0.9836**
Entropy	7.4169	7.8218	7.1761	7.7350	7.4636	**7.9741**
MSE	0.6233	0.5868	0.6401	0.6026	0.6512	**0.7115**
UIQI	0.8239	0.8265	0.8065	0.8362	0.7887	**0.8933**

TABLE 3. Objective quantitative evaluation of the full scale and degraded scale experimental results of QuickBird data

Method	Brovey	HIS	Guided	NSCT	PCA	Proposed
CC	0.9972	0.9973	0.9921	0.9958	0.9799	**0.9983**
Entropy	5.9638	6.5186	5.9490	6.1941	6.3978	**7.0660**

MSE	0.5515	0.6321	0.6683	0.5968	0.6435	**0.6942**
UIQI	0.8914	0.8895	0.8775	0.9085	0.8780	**0.9386**

Full scale – Entropy, spatial frequency, degraded scale – CC, FMI.
Hence full scale parameters are obtained with resultant image alone and Degraded scale parameters are obtained by using a reference image along with the resultant image.

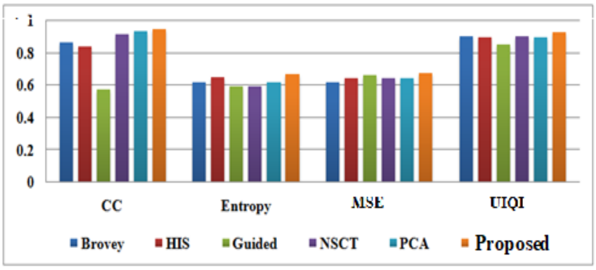


FIGURE 8. Quantitative evaluation of the Landsat-7 ETM+ data fusion results. (The quantitative assessment indices i.e. CC, Entropy, MSE and UIQI are described in section IV.)

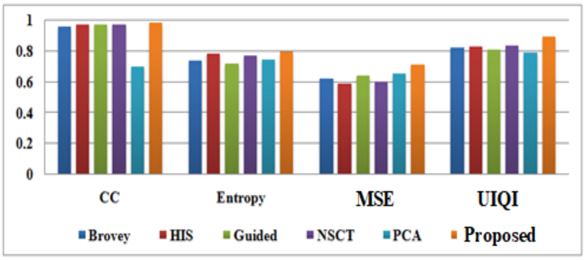


FIGURE 9. Quantitative evaluation of the IKONOS data fusion results.

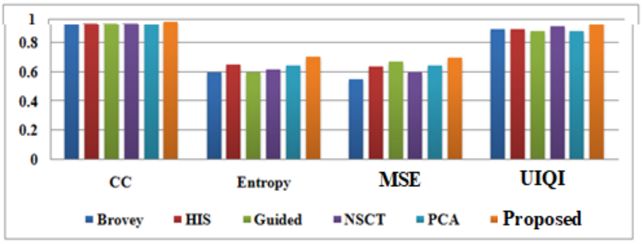


FIGURE 10. Quantitative evaluation of the QuickBird data fusion results.

CONCLUSION

In this research, we proposed a novel method for satellite image fusion that fuses Multispectral and Hyperspectral image to obtain high information on spectral and spatial details of the satellite image. The method used for image fusion using NSCT and FDCT method that gives a better decomposition of high and low frequency components for satellite image. Using NSCT and FDCT methods the multispectral and Hyperspectral images are processed and the resulted images is taken inverse and fused using max fusion rule and finalized fused image is resulted and the resulted single image contain have more information. And result has been compared with Brovery, HIS, GUIDED, NSCT and PCA by means of CC, Entropy, SF and FMI which shows that our proposed method gives a better performance in satellite image fusion.

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