

# Non-Subsampled Contourlet Transform (NSCT) Based Pan-Sharpener Method for Remote Sensing Images

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*Abstract:* — In this paper we present nsct for remote sensing images. The nsct (non-subsampled contourlet transform) is a fully shift-invariant, multiscale, and multidirectional expansion that has a fast implementation. On nsct two methods are based for pan-sharpening. In this paper different decomposition levels are used for both multispectral (ms) image and pan image which in order helps us to inherit spectral and spatial qualities of image and also reduces computation time. Only after nsct upsampling can be performed for ms images. Upsampling is essential since it enables us to preserve initial features, structure and information of ms images so they remain differentiable. Thus, at the same fine level this property is used for integration of pan image with ms image for pan-sharpening. Spectral and spatial image resolution have achieved better results.

Index terms—Nsct (non-subsampled contourlet transform), pan-sharpening, upsampling, remote sensing.

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## I. INTRODUCTION

The image quality can be improved by obtaining good results for both spectral resolution and spatial resolution. Earth observation satellite system are unable to provide images with both high spatial and spectral resolution due to different constraints. To obtain desired image that is image having both high spatial resolution and high spectral resolution we need to use Pan-sharpening process. Satellite sensors produce, on the one hand, panchromatic images (Pan) with high spatial resolution and low spectral resolution. On the other hand, they produce multispectral (MS) images with high spectral resolution and low spatial resolution. The integration of spatial information, extracted from the Pan image, into the MS image, provides an image with both high spatial resolution and high spectral resolution. This is known as pan-sharpening [1]. The inverse relationship [2] follows between spectral and spatial resolution. In particular the Pan-Sharpener that is a branch of data fusion devoted to the improvement of multispectral data quality by merging multispectral and panchromatic data characterize by complementary spatial and spectral resolution by Chavez in 1991. Among various the one algorithm based on merger of adaptive PCA approach [2] and Contourlet. The method IHS (Intensity Hue Saturation) transform [3] have colour distortion problem although it is highly reliable for image fusion. The proposed method in [4] uses the Normalized

Difference Vegetation Index (NDVI) to correct pan-sharpened images. In this paper NSCT based Pan-Sharpener algorithm is explained via two methods where first is the standard method and second one is more efficient improving the standard method. The remaining of the paper is described as follows. Section II describes NSCT. Quality indices are explained in Section III use to assess Pan-sharpened images. Section IV describes the standard NSCT based Pan-Sharpener method. Section V describe the two designed methods explaining importance about upsampling based on NSCT. Experimental results with their evaluation are presented in Section VI. Paper conclusion is in Section VII.

## II. NON-SAMPLED CONTOURLET TRANSFORM

Usually, pan-sharpening is conducted utilizing a multilevel decomposition to disunite high and low frequencies. Different techniques of Pan sharpening are predicated on multiresolution analysis utilize various methods of multilevel decomposition to decompose MS and Pan images, and then inject spatial details extracted from Pan, but missing in MS, into MS images [1].

Shift-invariant version of CT having some excellent properties including both multilevel and multidirectional [11]. properties is NSCT [1]. NSCT able to design better representation of contours. Laplacian pyramid

for multiscale decomposition and the DFB for directional decomposition is employed by CT. Reduction in the frequency aliasing of CT and to reach the shift invariance, downsamplers and the upsamplers are eliminated by NSCT during decomposition and reconstruction of image; that is designed on non-subsampled pyramid filter banks (NSPFBs) and the non-subsampled DFBs (NSDFBs), as illustrated in Fig. 1 [15]. NSCT, employs NSPFB is a 2-D two-channel non-subsampled filter bank (NFB). To obtain multiscale decomposition, logically kindred to the 1-D non-subsampled wavelet transform computed with the “à trous algorithm,” the filters for the next stage are achieved by upsampling filters of the antecedent stage including sampling matrix [9]

$$D = 2I = \begin{bmatrix} 2 & 0 \\ 0 & 2 \end{bmatrix} \quad (1)$$

Which gives the multiscale property without the need of additional filter design.

NSCT employs NSDFB, is a shift-invariant version of the critically sampled DFB in CT. DFB is constructed by combining critically sampled two-channel fan filter banks and resampling operations, which results in a tree-structured filter bank that splits the 2-D frequency plane into directional wedges [9]. NSDFB is constructed by

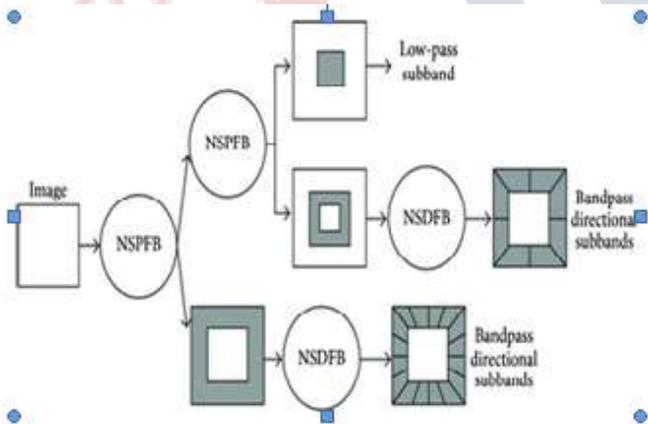


Fig. 1. NSFB structure that implements NSCT

Eliminating the downsamplers and upsamplers in DFB and as a result, NSDFB is also a two-channel NFB. To Obtain Multidirectional decomposition, NSDFB is iteratively used. NSCT is obtained by combining NSPFB and NSDFB [1], as shown in Fig. 1.

### III. QUALITY INDICES

The quality assessment of the pan-sharpened MS images presents a problem since no reference image exists at the pan sharpened resolution. In this paper, we have selected the following widely used indices for assessing the quality of the obtained results [1].

1) The correlation coefficient (CC) [5]: It is the most popular. It measures the similarity between the fused and original images. A CC value of indicates that the two images are highly correlated or similar.

2) The relative bias (BIAS): It is the difference between the mean of the original image and that of the fused one, divided by the mean of the original image [5].

3) The relative variance (VAR): It represents the difference in variance between the original and fused images, divided by the variance of the original image [5].

4) The standard deviation (SD) of the difference image in relation with the mean of the original image: It indicates the level of **the error at any pixel** [5].

5) The root-mean-square error (RMSE) [5].

6) The Peak-Signal-to-Noise-Ratio (PSNR): The ratio between the maximum possible power of a signal and power of corrupting noise that affects the fidelity of its representation.

7) The Percentage Residual Difference (PRD)

The best value for indices CC is 1, whereas it is 0 for indices BIAS, VAR, SD, and RMSE.

### IV. STANDARD NSCT BASED PAN-SHARPENING

Usually, all the multiresolution-predicated pan-sharpening methods follow these steps [7].

1) Forward transform the Pan and MS images utilizing a sub-band and a directional decomposition such as subsampled or non-subsampled wavelet or contourlet transform.

2) On the transform coefficients fusion rule is applied.

3) Using the inverse transform pan sharpened image is developed.

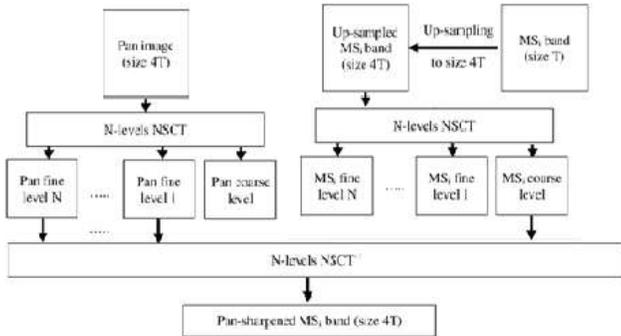


Fig. 2. Standard nsct-based pan-sharpening method for  $i$ th band ( $ms_i$ ) [1].

Fig. 2 shows an example of an NSCT-based pan-sharpening method. For every MS band, the pan-sharpened

NSCT coefficients are obtained by combining the coarse level coefficients of the corresponding MS band and the fine levels coefficients of the Pan image. By using NSCT inverse transform corresponding pan-sharpened MS band can be generated.

## V. NSCT BASED PAN-SHARPENING METHODS

In this paper two methods are described in the following. The first one shows the efficiency obtained when using different number of decomposition levels; whereas the second one demonstrate better results by considering an upsampling method based on NSCT.

### A. Method I: NSCT-Based Pan-Sharpening With Different Numbers of Decomposition Levels [1]

By studying [12] the estimation of the number of decomposition levels for a wavelet-based multiresolution multisensory image fusion. We found that a lower number of decomposition levels inherit better the spectral quality, whether a higher number of decomposition levels is referred to maintain the spatial quality. Adequate number of decomposition levels are utilized to obtain improved fused image. Consequently, we decided to use the NSCT based pan-sharpening where number of decomposition levels is different, MS band decomposition level is lower than the pan image decomposition level.

For different satellites, as WorldView-2, Quick Bird, and IKONOS, the resolution ratio is 1:4 between MS and Pan [1].

### B. Method II: NSCT-Based Upsampling and Pan-Sharpening With Different Numbers of Decomposition Levels [1]

Typically, before the pan-sharpening process MS images are resampled to the same pixel size as the Pan image.

#### 1) NSCT-Based Upsampling:

Upsampling holds important role in a pan-sharpening process. Quality of the pan-sharpened Images can be improved by performing.

- First, using NSCT MS image is decomposed.
- On resulting NSCT coefficients interpolation is performed.
- Through inverse NSCT upsampled image is generated, applied to the interpolated coefficients.

#### 2) NSCT-Based Pan-Sharpening :

Fig. 2 demonstrates how standard NSCT based Pan-sharpening works. Improvement in Fig. 2 can be presented by considering different number of decomposition levels (for both MS image and Pan Image) and the placement of the interpolation method based on NSCT. The flowchart of this designed method is illustrated in Fig. 3, where the improvements are highlighted. Pan-sharpening process is performed as described by the following steps.

- Utilizing NSCT, the Pan image is decomposed into one coarse level and three fine levels whereas each original MS<sub>i</sub> band is decomposed, in one coarse level and one fine level.
- Utilizing the bi-linear interpolation algorithm the obtained MS<sub>i</sub> coefficients are then up sampled.
- Up sampled coarse level of the MS<sub>i</sub> band is the coarse level of the pan-sharpened MS<sub>i</sub> band.
- Fine levels 2 and 3 of pan-sharpened MS<sub>i</sub> band are set to fine levels 2 and 3 of the pan image.
- By fusing the coefficients of the same level obtained from both the MS<sub>i</sub> band and the pan image we achieve fine level 1 of the pan-sharpened MS<sub>i</sub> band. The local energy (LE) of each coefficient [13] calculated within  $(2M + 1) * (2N + 1)$  window to generate a decision map utilizes the fusion rule. For the  $(x, y)$  position, the LE is given by

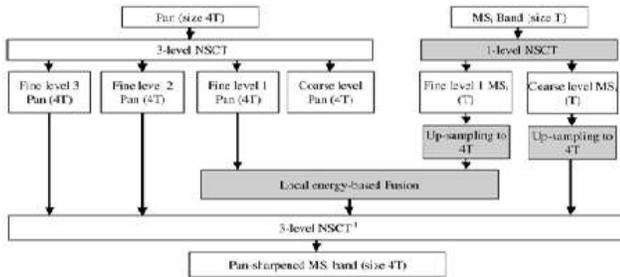


Fig.3. Method II: NSCT-based pan-sharpening method for an  $i$ th band ( $MS_i$ ) [1]

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

This map is used in order to decide whether pan coefficient or ms coefficient will be used, according to following Formula

$$\text{Fused\_fine\_level\_coeff}(x, y) = \begin{cases} MS\_fine\_level\_coeff(x, y), & \text{if } LE_{MS}(x, y) \geq LE_{pan}(x, y) \\ Pan\_fine\_level\_coeff(x, y), & \text{otherwise} \end{cases} \quad (3)$$

f) Finally, to obtain the pan sharpened images  $MS_i$  we need to perform inverse nsct.

## VI. EXPERIMENTAL RESULTS

In this section, the two methods are evaluated to obtain pan-sharpened images. Pan image is a gray scale image whereas MS image is a colour image having three different panels red, green and blue. NSCT will support only 8 bit images. So, if we want to apply transforms on our input colour image first we need to perform panel separation after that we can apply transform for R (Red) panel, G (Green) panel, B (Blue) panel individually and reconstruct it. Size of Pan Image is already 8 bit but MS image is of 24 bit so in order to apply transform first we need to separate 3 panels and then we can perform transformation. After separation each panel is of 8 bit.

In this paper, the standard NSCT-based method is noted "standard", the method described in Section V-A is called "method1", and finally the improved method described in Section V-B is referred to as "method2". Fig. 4

illustrate the example of pan-sharpened images based on the two methods described above in section V. Visually, the resulting images appear similar. We can notice that there are no major differences noticeable to the naked eye. However the quality indices vary for every set of input images (Pan Image and MS image)

From Table II we can conclude that

a) The "Method I" is achieving good results, for different images in terms of quality indices CC, RV, PSNR.

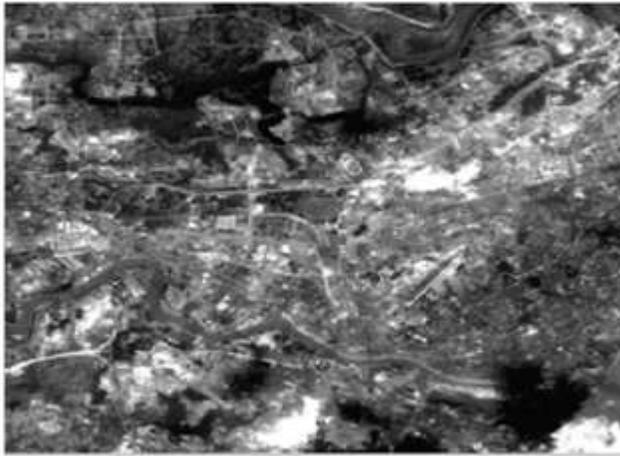
b) The "Method II" i.e. improvement in method I by applying upsampling is achieving good results, for different images in terms of quality indices CC, RV, PSNR. It provides best results in terms of quality indices RMSE, RB, PRD, SD.

Table II demonstrates the two methods. From all the tables, graphs and resulting pan-sharpened images we can conclude that "Method II" achieves the best results in terms of both spatial and spectral qualities. The "method1" is good in terms of preserving spectral quality compared to the standard method, whereas providing the same spatial quality as that of the standard method.

TABLE I

Quantitative assessment of pan-sharpened images (3)

Index	pan-sharpening method	
	Method i	Method ii
Correlation coefficient	0.9854	0.9851
Relative bias	0.0627	0.0627
Relative variance	0.0051	0.0025
Rootmean square error	2.9393	2.9803
Percentage residual difference	0.0260	0.0264
Peak signal to noise ratio	43.4484	43.3883
Standard deviation	7.2803	7.2755



a) Pan Image



c) Method I Resulting Image



b) MS Image



d) Method II Resulting Image

Fig 4. Method II NSCT Based Pan-Sharpening Image

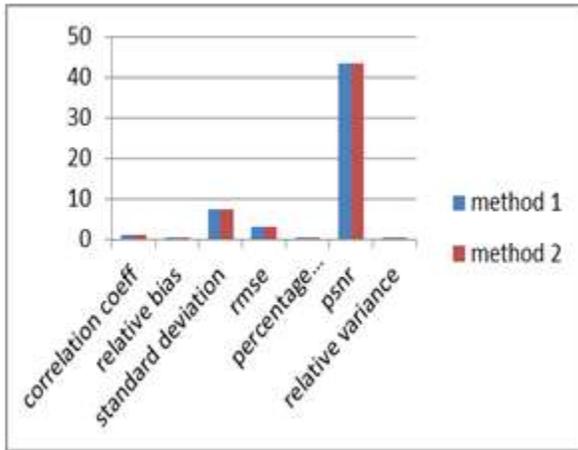


Fig 5. Quality Indices of Pan-Sharpended Image

TABLE II

Quantitative Assessment Of 3 Pan- Sharpended Images

Pan-Sharpending Method		CC	RB	RV	RMSE	PSNR	PRD	SD
Image 1	Method I	0.8603	0.3106	0.1572	13.7202	35.7572	0.1211	7.4915
	Method II	0.8602	0.1307	0.1582	13.7240	36.7560	0.1212	7.4904
Image 2	Method I	0.9765	0.1288	0.0442	10.4750	37.8187	0.0998	8.1738
	Method II	0.9711	0.1277	0.0420	10.7487	37.8172	0.0999	8.1696
Image 3	Method I	0.9854	0.0627	0.0051	2.9393	43.4484	0.0260	7.2803
	Method II	0.9851	0.0627	0.0025	2.9803	40.0260	0.0264	7.2755

## VII. CONCLUSION

In this paper, the NSCT-based pan-sharpening method in its standard forms is considered. The improvement of the NSCT-based image pan-sharpening is achieved by using a higher number of decomposition levels for the pan image and a low number of decomposition levels for ms images. This method enables us to obtain satisfactory results. The method i provides pan-sharpened image with good spectral quality only. To obtain resulting images with good spectral quality and to inherit existing basic features in the ms image we put emphasis on upsampling. upsampling is performed after NSCT. thus we perform interpolation in second method after NSCT in

addition to different decomposition levels for both pan and ms images. the obtained fine levels from ms and pan images are fused using the le (local energy) as the fusion rule. quality indices and pan-sharpened images obtained from the two methods are satisfactory with improved quality.

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