Performance Analysis of IHS and Wavelet based Integrated Pan Sharpening Techniques

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ABSTRACT
Pansharpening technique is used for fusion of low spatial resolution multispectral image and high spatial resolution panchromatic image, to increase the spatial resolution of multispectral image. Intensity-Hue-Saturation pan sharpening method has been used for most of the practical pansharpening applications but it offers some spectral distortion. Therefore, it has been used in integration with wavelet transform based pansharpening technique because wavelet transform based pansharpening techniques preserve spectral information via multilevel decomposition. In this paper, the integrated IHS and wavelet based pansharpening technique has been implemented using different types of wavelet transforms. Different fusion rules have been used for fusion of corresponding details and approximation coefficients obtained by multilevel decomposition of images for implementation of integrated pansharpening technique. The results have been analysed and compared using some important image quality metrics like spatial and spectral correlation coefficient, entropy and root mean square error and conclusions have been drawn.

General Terms
Pansharpening of multispectral images, Intensity Hue Saturation base pansharpening technique, Wavelet based pansharpening technique, the integrated approach.

Keywords
Image fusion, pansharpening, multispectral, IHS, wavelets.

1. INTRODUCTION
Image fusion is a technique of combining the information of two or more images into a single image so as to get enhanced perception of a scene from that single image. The need of image fusion arises when images taken from a scene are not communicating the complete information individually. This might be due to poor resolution of the image sensor, improper capturing of an image, due to movement of sensor or the objects to be sensed, or due to degradations like optical degradation, sharpness reduction, halo artifacts, ringing effects, artificial edges and other deformations [1]. In the field of remote sensing, due to cost and complexity issues, the images captured by satellite sensors are either multispectral (MS) images, having high spectral and low spatial resolution or panchromatic (pan) images, having high spatial and low spectral resolution. There lies a tradeoff between spatial and spectral resolution of captured images. Therefore the spatial resolution of MS images needs to be enhanced to get complete information of a scene. Pansharpening is a process of fusion used for increasing the spatial resolution of a low spatial resolution multispectral image using a high spatial resolution panchromatic image, while preserving its spectral information. This is accomplished using image fusion of MS and pan image so that the fused image is a pansharpened MS image having a spatial resolution comparable to pan image and spectral resolution of the MS image itself. The pansharpened MS image is used to observe the remote objects, classification and change detection.

In recent years, many pansharpening techniques have been proposed, which can be classified among two categories- Component Substitution (CS) and Multiresolution Analysis (MRA) [2]. The CS method is based on replacing a component of MS image, that contains the spatial information with the pan image while the MRA method is based on multiscale decomposition of pan image to extract the information and then inserting the extracted information into the MS image. The CS methods mainly include Intensity Hue Saturation (IHS) method, Principle Component Analysis (PCA), Gram Schmidt method and Brovey method [3,4]. These methods have low computational complexity and also maintain the spatial resolution but offer some spectral distortion while the MRA methods like wavelet transform or laplacian pyramid method lower the spectral distortion but offer some spatial distortion. There are also some methods like variational methods and the methods based on statistical estimation those do not belong to either category [5]. Therefore a method that integrates both CS and MRA techniques need to be used. In this paper, an IHS and wavelet integrated approach is discussed so as to attain high spatial as well as spectral resolution with minimum distortion.

2. IHS AND WAVELET PANSHARPENING METHODS
Among the various pansharpening techniques available in literature, the Intensity-Hue-Saturation pansharpening technique is the most widely used in practical applications due to its low complexity and cost issues. It injects the spatial details of pan image in MS image effectively but it offers color distortion in the pansharpened image thus degrading the spectral quality of MS image. The wavelet image fusion method has many advantages over other methods, one of them being spectral preservation, making it applicable in advanced applications of image fusion. Therefore the IHS method is used along with the wavelet based image fusion method to utilize the distinct advantages of two methods.

2.1 IHS pansharpening technique
The Red-Blue-Green (RGB) color space is most commonly used by computer system to display the color information. IHS is another color space that effectively represents the color image in the form of intensity, hue and saturation components [6]. In IHS color space, the spectral information of a color image mainly lies in hue and saturation components and the

spatial details are enclosed in intensity component. This property of color images is used to implement pansharpening using IHS method as shown in Figure 1. To implement pansharpening using IHS method, the MS and pan images are first registered to eradicate the spatial misalignment of two images, if any. Then the MS image is first converted from RGB to IHS color space. Then the histogram of I component of MS image is matched with the histogram of pan image to achieve superior fusion results. Then the intensity component of MS image is replaced with pan image and the resultant image is converted back to RGB color space to get the final fused image [7].

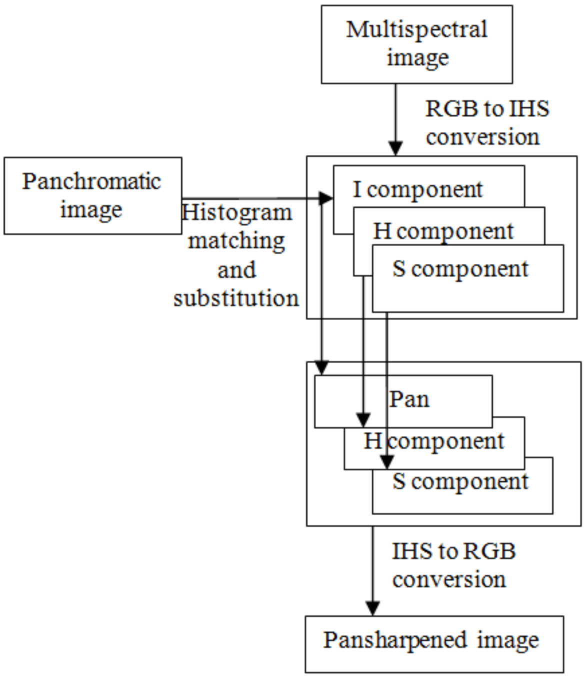


Fig 1: IHS pansharpening technique

The transformation of image from RGB to IHS color space is carried using certain set of formulae which are represented by the following equations (1-4).

$$I = (R + G + B)/3 \quad (1)$$

$$H = \begin{cases} \theta, & for\ B < G \\ 2\pi - \theta, & for\ B > G \end{cases} \quad (2)$$

where,

$$\theta = \cos^{-1}\frac{0.5*((R-G)+(R-B))}{\sqrt{(R-G)^2+(R-B)*(G-B)}} \quad (3)$$

$$S = 1 - \frac{3(\min(R,G,B))}{(R+G+B)} \quad (4)$$

2.2 Wavelet transform based pansharpening technique

For multiresolution analysis, wavelet transform can be applied to images to get low frequency coefficients called approximation coefficients and high frequency coefficients called details components [8]. The details coefficients contain spatial information and the approximation coefficients contain the spectral information. The image is first decomposed using some wavelet transform like Haar, Daubechies, Dual Tree Complex Wavelets, Coiflet, Coifmann wavelet transforms at required level of decomposition. The multilevel wavelet decomposition at level-2 has been shown in Figure 2. The approximation and details coefficients thus obtained are fused individually using same or distinct fusion rules like choose min, choose max, mean, random or another fusion approach. The inverse discrete wavelet transform (IDWT) is then applied to get the pansharpened image [9]. This technique has been explained in Figure 3.

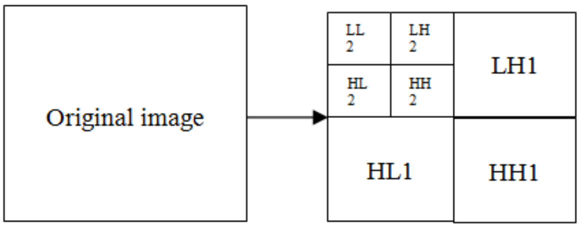


Fig 2: Level-2 Wavelet decomposition

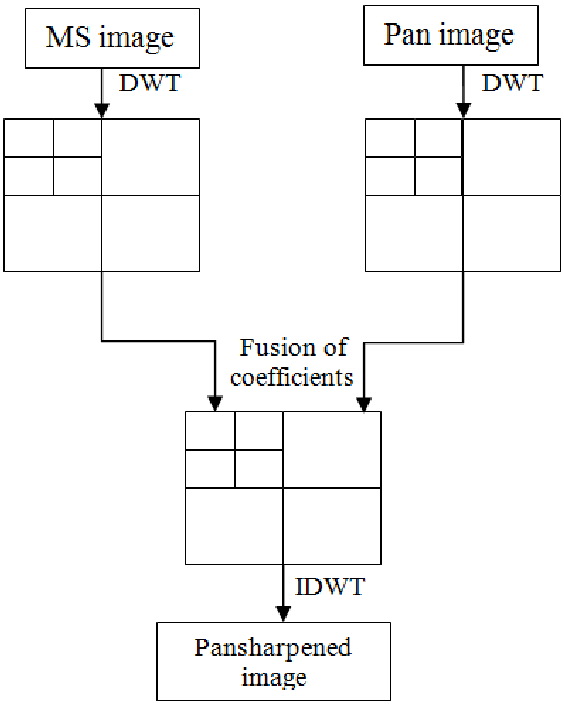


Fig 3: Wavelet based pansharpening technique

3. IMPLEMENTATION OF IHS AND WAVELET INTEGRATED PANSHARPENING SCHEME

The IHS pansharpening method and wavelet based pansharpening method are most commonly used pansharpening methods but both of them have some virtues and some drawbacks. The IHS pansharpening method gives the results with good spatial resolution but the outputs are usually distorted in color, that is, some of the spectral information is lost. The problem of spectral distortion is resolved using wavelet transform based pansharpening method as it produces fusion results retaining most of the spectral information but some of the spatial information gets lost. Therefore, there exists a trade-off between spatial and spectral quality of the pansharpened image. Thus an integrated IHS and Wavelet based pansharpening technique is used to maintain both spatial information of pan image and spectral information of MS image. In the literature, various fusion methods have been used for fusion of approximation and details coefficients [10]. In this paper, different wavelet transforms have been applied and different combinations of fusion rules have been proposed for approximation and details coefficients and the results have been compared. The proposed method is implemented using the following steps.

1. The original MS image is converted from RGB to IHS color space.
2. The histogram of panchromatic image is matched with the histogram of Intensity component of MS image.
3. The pan image and the intensity component of MS image are decomposed at level-2 and the corresponding approximation and details coefficients are fused using a set of fusion rules.
4. An inverse discrete wavelet transform (IDWT) is applied on the image thus obtained.
5. The intensity component of original MS image is replaced by the image obtained in step 4.
6. The image is then converted back from IHS to RGB color space to get the final pansharpened MS image.

The integrated IHS and wavelet based pansharpening technique has been demonstrated in Figure 4. The technique has been implemented using various waveform transforms and various fusion rules for fusion of corresponding approximation and details coefficients.

4. RESULTS AND PERFORMANCE ANALYSIS

The integrated IHS and wavelet based technique has been implemented using different types of wavelets and different set of fusion rules. The results have been implemented using a dataset consisting original MS image and a panchromatic image [11]. Initially, the intensity component of MS image and pan image are decomposed using different wavelets, namely, Haar, Daubechies, Symlets, Coiflets, Dmeyer, Orthogonal and Reverse Orthogonal wavelets at level-2 of decomposition and fusion of corresponding approximation coefficients using only MS image and details coefficients by using mean rule. The results using IHS based pansharpening, Wavelet based pansharpening and integrated pansharpening technique has been shown in Figure 5. Qualitative analysis can be done by visual inspection and the quantitative analysis of results is done by calculating and analysing the image quality metrics [12]. The spatial quality has been analysed using correlation coefficient (CC) between high spatial resolution pan image and the pansharpened MS image and the spectral quality is analysed using some metrics like spectral correlation coefficient between original and pansharpened MS image, entropy (E) of original and MS image and root mean square error (RMSE). Table 1 presents the values of quality metrics for IHS based, wavelet based and integrated pansharpening technique. The comparison of quality metrics for IHS based, wavelet based and integrated pansharpening algorithm has been shown using bar graphs in Figure 6.

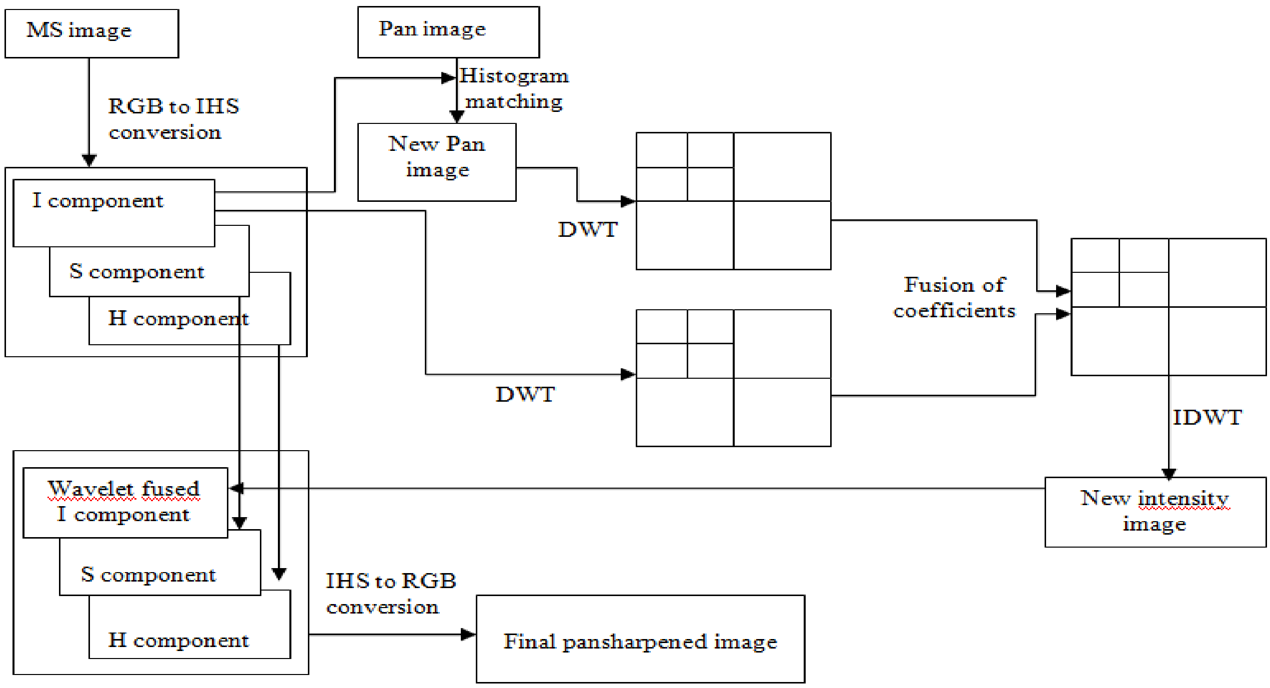
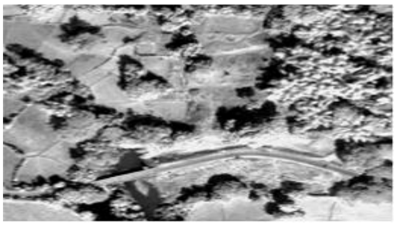


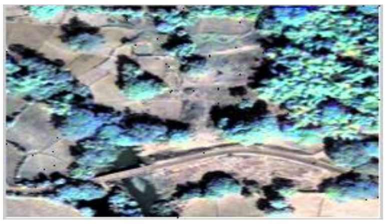
Fig 4: Integrated IHS and Wavelet transform based pansharpening technique

The integrated IHS and wavelet transform pansharpening technique has also been implemented using different fusion rules like choose min, choose max, mean etc. The Intensity component of MS image and the pan image have been decomposed into approximation and details coefficients at level-2 and the corresponding coefficients have been combined using different sets of fusion rules, by using same or distinct fusion rules for approximation and details coefficients and the results have been shown in Figure 7. Tables 2-3 represent the values of pansharpened image quality metrics using different wavelets and different sets of fusion rules respectively.

(a) Original MS image



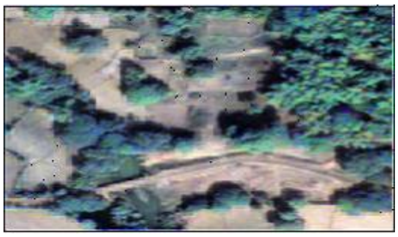
(b) Pan image



(c) Using IHS pansharpening method

(d) Using wavelet based pansharpening

(e) Using IHS and Haar Wavelet integrated approach



(f) Using IHS and daubechies wavelet integrated approach

Fig 5: Results of pansharpening of MS image using IHS based, wavelet based and integrated pansharpening techniques

The visual analysis of pansharpened images in Figure 5 shows that IHS based pansharpening image results show good spatial quality but it carries spectral distortion while the wavelet based pansharpened image shows no spectral distortion but some spatial degradation is there. But in the IHS and wavelet integrated technique, both spatial and spectral qualities are good. The values of quality metrics given in Table 1 also strengthens the conclusions drawn from visual analysis, as the value of both spatial and spectral correlation and entropy is high both integrated pansharpening technique and the value of RMSE has decreased. This has also been demonstrated using bar graphs in Figure 6.

Table 1. Quality metrics for results of pansharpening of MS image using IHS based, wavelet based and integrated pansharpening techniques

Pansharpening technique	Spatial CC	Spectr-al CC	E	RMSE
IHS	0.8122	0.4608	7.7729	7.1238
Wavelet	0.4852	0.8766	7.6736	8.0293
Integrated	0.7175	0.7201	7.7685	6.5374

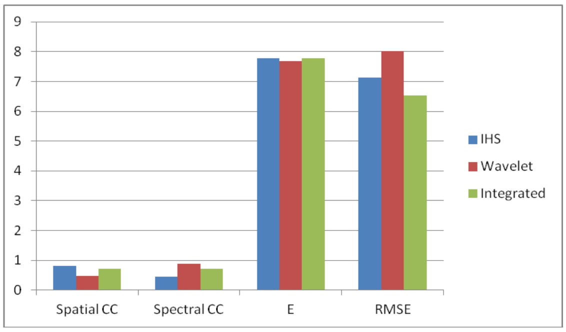
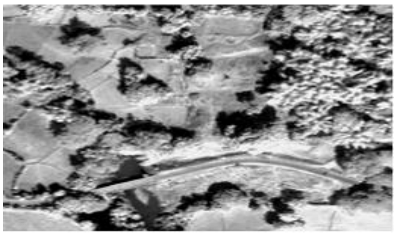


Fig 6: Quality metrics for IHS based, Wavelet based and integrated technique

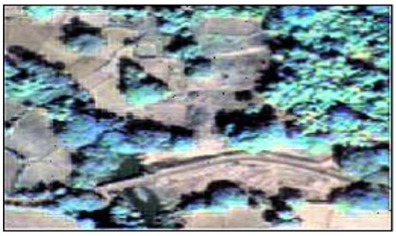
The quality metrics of results of IHS and wavelet integrated pansharpening using different wavelets have been given in Table 2. The spatial correlation coefficient is highest using Haar wavelet and spectral correlation coefficient is almost same for using all the wavelets, which implies that all wavelets are preserving the spectral characteristics of MS image due to multilevel decomposition. The entropy is almost same for all the wavelets used while the value of RMSE is minimum for Haar wavelet. Therefore, the Haar wavelet is one of the widely used wavelet transforms.

When different sets of fusion rules are used for approximation and details coefficients, the visual analysis from Figure 6 shows that the best spatial details are given by fusion of approximation coefficients by replacing them by approximation coefficients of pan image and keeping the details coefficients as it is and the spectral quality is best while fusing the approximation coefficients using mean rule and the Table 3 verifies the same. The entropy is maximum when approximation coefficients are replaced with those of pan image and keeping the details coefficients as it is. The value of root mean square error is minimum when approximation coefficients and details coefficients are fused using max and mean rule respectively.

(a) Original MS image

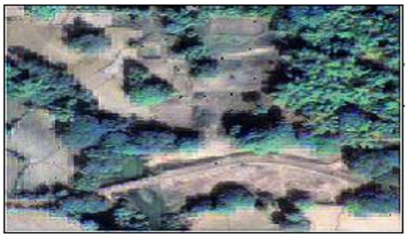


(b) Pan image



(c) Img2, Img1

(d) Mean, Img1



(e) Mean, Max

(f) Mean, Mean

Fig 7: Results of pansharpening of MS image using different sets of fusion rules (fusion rule for approximation coefficients, fusion rule for details coefficients).

Table 2. Quality metrics for results of pansharpening of MS image using different wavelet transforms

Type of wavelet used	Spatial CC	Spectr-al CC	E	RMSE
Haar	0.5162	0.8924	7.6800	7.7200
Daubechies	0.4985	0.8403	7.6989	8.1872
Symlets	0.4992	0.8378	7.7088	8.3171
Coiflets	0.4878	0.8779	7.7427	8.2786
Dmeyer	0.4643	0.8916	7.6675	7.7946
Biorthogonal	0.4830	0.9051	7.6912	7.8277
Reverse Bior	0.4595	0.8742	7.7020	8.4085

Table 3. Quality metrics for results of pansharpening of MS image using different set of fusion rules (fusion rule for approximation coefficients, fusion rule for details coefficients)

Fusion rules used	Spatial CC	Spectr-al CC	E	RMSE
Img2, img1	0.7649	0.3650	7.7992	7.2108
Img2, Mean	0.6788	0.3602	7.7733	7.22822
Max, Max	0.6700	0.4423	7.7930	5.1820
Max, Mean	0.7522	0.5176	7.7725	3.9595
Mean, Img1	0.6821	0.4675	7.7713	7.0521
Mean, Max	0.6722	0.6395	7.7802	7.1519
Mean, Mean	0.7175	0.7201	7.7685	6.5374

5. CONCLUSION

The IHS and wavelet integrated pansharpening technique has been presented in this paper and results have been compared with IHS based pansharpening technique and wavelet based pansharpening techniques. The integrated technique gives better results with high spatial resolution pansharpened MS image, while preserving its spectral resolution. In this paper, different types of wavelet transforms and different sets of fusion rules have been used to implement integrated pansharpening technique and the comparison has been made. The results and their analysis show that different combinations of wavelets and fusion rules can be used for implementing IHS and wavelet based integrated pansharpening technique depending on the requirement and application of pansharpening.

6. REFERENCES

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