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Comparison of Different Image Fusion Algorithm on Remote Sensed Data

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A B S T R A C T

Quality assessment of pan sharpening fusion methods used for classification of images is the objective of this article. The technique of combining panchromatic image having high spatial resolution with image having lower spatial resolution is known as pan sharpening. Care must be taken so that spectral characteristics of multispectral data should be preserved while carrying pan sharpening process. Three different methods of image fusion are compared to show their ability to fuse image data from IRS P-6 sensor (PAN data 2.5m) and IRS P-5 sensor (LISS IV data 5.8m). The obtained fusion images are analyzed visually and quantitatively to obtain spatial improvement and preservation in characteristics. Compared to all fusion methods, WT+HIS fusion method is superior and it is the only algorithm which guarantees good color preservation of the data and sensor used.

Keywords: Image fusion, pan sharpening, classification, quality assessment.

Introduction

The process of joining two or more than two images to form a new image by using any algorithm is called Image fusion. The purpose of image fusion technique is to integrate different types of data (multi-spectral image, radar microwave image, etc.) in order to receive more information The best traditional fusion techniques are: multiplicative technique (MT), Brovey transformation (BT), principal component analysis (PCA) method, and intensity-hue-saturation (IHS); currently the wavelet transformation method is also under investigation. Generally the fusion method can be performed using three processing levels like (a) pixel level (b) feature level and (c) decision level. Pixel-methods are considered to be arithmetic and contribution methods. Examples: BT, addition and multiplication, SFIM, and HP Filtering [2,3,4]. To increase the information content associated with each pixel of the image, Pixel level method is used.

The feature level includes the most of the transform and substitution methods such as IHS, PCA, pyramid class with its derivatives, wavelet transform family with its descendants, fuzzy logic and spatial modeling [5-7].

Despite the investigations and comparisons made on image fusion techniques, still, the image fusion approach needs to answer a few of the following major questions [8]:

- Which technique is the *best* to fuse data to meet the objective of user?
- Which combination of the data is the most successful one for classification?

Hence, in the above context, best fusion technique is a prerequisite for accurate image classification. Obtaining satisfactory accuracy in classification for urban/ semi urban land usage especially in high spatial image is a challenging task [9].

Study Area

The area under investigation is The National Institute of Technology Karnataka (NITK), Srinivasnagar, Surathkal campus, located 22 km North of Mangalore City on the coastal belt of Karnataka State, India. The campus is spread over an area of approximately 300 acres of land between 13º 00' 15"-13º 01' 05" N latitude and 74º 47' 15"-74º 48' 02" E longitude. The study area dimension is 1000x985 pixels. It has a good mixture of spectrally overlapping classes comprising of man-made structures and natural land cover features (Fig 1). Although the campus runs along the beach without extending into the Arabian Sea, a small portion of the sea has also been included in the imagery to study the behavior of the classifiers on sea water and pool water.

Fig 1. Study area: The National Institute of Technology Karnataka, India

Material and Methodology

Data used and Data preparation

IRS-P6 LISS-IV satellite data captured on December 26th 2007 (path: 104, row: 026; 5.6 m spatial resolution) consisting of three multispectral (MS) bands recorded at green (0.51-0.59µm), red (0.63-0.68µm) and infrared (0.77-0.86µm) wavelengths, and a panchromatic imagery of CARTOSAT-1 captured on 7th January 2008 (path: 0531, row: 335; 2.5 m) are used in this study. Both the data were fused together to derive the best class separation features from their spectral as well as spatial resolutions.

Data Fusion

For an exact and description of structure and shapes, fine spatial resolution is required whereas for discriminating between various classes in spectral spectral resolution is used. These two techniques are complementary in nature, combining these two types of data is beneficial for obtaining more information from the image interms of spectral and spatial resolution, it is known as panchromatic sharpening(PS). In this study, in order to select the best fused data, we first accomplished data fusion by employing the three commonly used pixel level RS data merging techniques called principal component analysis (PCA), IHS and Wavelet+IHS.

Principal Component Transform

In order to transform a multivariate correlate variables into uncorrelated variables principal component transform is used. Instead of creating original multispectral feature space this transform creates uncorrelated feature space which can be used for further analysis and it is applied to the multispectral bands. It then replaces the selected component and an inverse PC transform takes the fused dataset back into the original multispectral feature space . The number of bands is not restricted in principle component transform that is the main advantage of this transform.

Intensity Hue Saturation

In order to separate spatial and spectral information from standard RGB image HIS transform is used. The total brightness of the image is indicated as intensity of the image which is comparable with the perception of the human. In order to fuse the mages, three different bands of multispectral images which are in RGB domain is transformed into IHS color space. The modified IHS fusion is used for fusing multispectral bands to the original data. If the number of bands are greater than 3 then IHS transform should be used more than once depending on number of bands to be fused.

Wavelet and HIS Transform Fusion

To preserve spectral color and enhanced spatial information is the main objective of fused image. To achieve this Hong et.al (2003) combined WT and IHS which can satisfy the above objective, based on their strengths and drawback. IHS causes significant colour distortions but preserves colour information by providing PAN image details which is similar to intensity in one channel. WT causes ringing effect in MS information but it preserves the colour information by enhancing the spatial resolution and transformation is done separately in three channels[25,26].

The following steps are used for WT and IHS fusion process

- Multispectral RGB image is transformed into IHS space with spatial (*I*) and spectral(*H*,*S*).
- Inverse WT is performed and new intensity is generated. The new intensity generated is transformed together with hue and saturation component to obtain RGB color space.
- Perform inverse WT and generate a new intensity and transform the new intensity, together with the hue and saturation component back in to RGB colourspace.

Results and Discussion

Determining the best fused data inorder to classify semi-urban LU/LC feature is the main objective of image fusion technique. Beside the proposed fusion Method DWTIHS for short), other two commonly used methods, i.e., the PCA based fusion method and DWT method are used for comparison. In the IHS-DWT method, the number of clusters C and the weight control constant λ are set to 30 and 20 respectively.

The images obtained from three fusion algorithms are presented along with the original MS image in Figs. 2(a) - 2(c) for visual analysis. The qualitative analyses of various bands of fused image are represented in Table 2 - Table 6, respectively. The correlation coefficient between various bands of fused image, original MS images is noted in Table 6 for statistical analysis.`

The evaluation process consist of

- Visual Interpretation
- Quantitative Analysis

Visual Interpretation

For qualitative assessment, visual comparision of all fused image is used which is very simple yet effective tool. Upon comparing visually the original MS image with pan-sharpened images, spatial resolution of resultant image is comparable to resolution of the original PAN image and it is higher than the original MS image.

In Fig 2 (a), PCA fusion technique indicates the resolution of the original MS image is improved and the technique preserves the spectral contents of the original image. Also, the PCA fusion technique preserves all the factors of the image that are essential for the identification of urban buildings. Trees can be distinguished clearly.

Fig 2 (b), indicates fusion based on IHS fusion method. We note that spatial resolution of the MS image has been improved. Also the colors of the image become darker. This IHS technique is preferred for detecting the objects Which has very high reflectance. The resolution of the fused image is also improved in wavelet+IHS technique i.e., Fig 2 (c). upon comparing transformed image with original MS image, the color of resultant image looks lighter.

(a). Fused Image for 2008 MS and Pan- HIS (b)Fused Image for 2008 MS and Pan- DWT (c) Fused Image for 2008 MS and IHS_DWT

Fig 2. Visual analysis of fused data

Table 1 depicts the comparison of different fusion techniques based on object detection

Table 1: Comparison of Fusion techniques based on object

	IHS	DWT+IHS	DWT
Building	Very Good	Very Good	Good
Trees	Very Good	Very Good	Poor
Road	Very Good	Very Good	Good

Quantitative analysis

From the Literature survey it is evident that the recovery of the original colors or spectral preservation is necessary for correct thematic mapping. Hence, in addition to the visual evaluation, the fusion techniques are also analyzed quantitatively to study the spectral distortion; we use statistical parameters such as standard deviation, correlation coefficient and entropy with MS and PAN images.

Graphical representation of a digital image can be obtained using Histogram. Graph is obtained by plotting a number of pixels for each tonal value.Mean Values of different bands of the MS and the resultant fused data. The Histogram-means of the three bands of the fused images are computed and are indicated in Table 2.

Table 2 Histogram-means of the fused images

	MS	IHS	HIS_DWT	DWT	PAN
Band1	107.5	49.4	43.3	107.4	
Band 2	75.5	110.9	41.2	115	
Band 3	115.3	47.5	40.8	75.4	79.25
Column Average	**99.43**	**69.26**	**41.76**	**99.26**	

Band 1: Green, Band 2: Red, Band 3: Infrared

To weight the image information standard deviation is an important index. The computed standard deviation of original image and the fused images are indicated in Table 3 and fig 3. The computation is carried out band wise.

Table 3 Standard deviation of different bands of the fused images

	MS	IHS	IHS_DWT	PCA	PAN
Band1	27.3	26.3	30.2	29.2	
Band 2	15.3	41.7	20.2	20.8	
Band 3	17.7	22.5	23.8	14.7	26.92
Column Average	**20.1**	**30.16**	**24.73**	**21.56**	

Band 1: Green, Band 2: Red**,** Band 3: Infrared

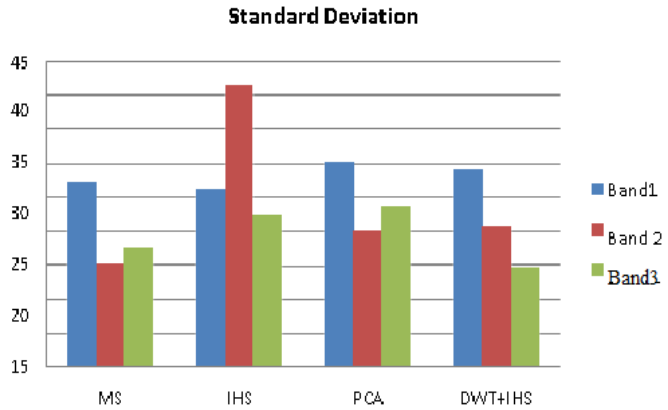

Fig 3. The Standard deviation of MS and the fused images.

The values of standard deviation vary slightly with respect to MS data. In Intensity hue saturation method mean values of all the bands are increased by twice when compared with MS band and standard deviation values of all the bands remain almost similar when compared with MS band.

Amount of information contained in the image defines the Entropy. Entropy depicts the average information of the image and it provides the detailed information of fused image. If Entropy of the fused image is greater than MS image then it means more information are included in it. Entropy of the original image and fused images were computed and it is shown in Table 4 and fig 4.

Table 4 Entropy of the fused images

	MS	IHS	IHS_DWT	PCA	PAN
Band1	6.24	6.30	6.25	6.48	
Band 2	5.52	6.86	5.56	6.08	
Band 3	5.66	5.93	5.69	5.37	6.26
Column Average	**5.80**	**6.36**	**5.84**	**5.97**	

Band 1: Green, Band 2: Red, Band 3: Infrared

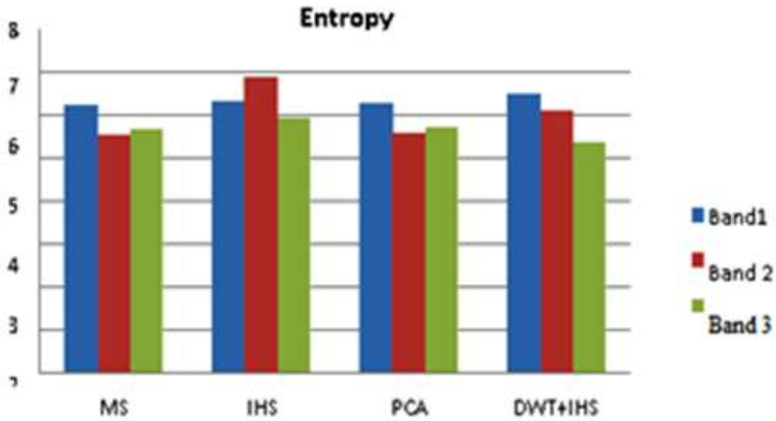

Fig 4. The Entropy of all the original MS and the fused images

The computed image entropy (MATLAB 2022 implementation) is provided in Table 5. The analysis indicates that MS data possesses the average entropy of 5.80 and PAN data possesses the highest entropy of 6.26 among the three images. The higher entropy exhibited by the PAN may be reasoned to the fact that PAN shows greater details of information since the spatial resolution of PAN is higher than the original MS data. However, this hypothesis is not true on one of the fused data, the MT image. The entropy of the IHS is 5.97, which is less than the entropy of the original MS data (5.9464). Further, WT+IHS (entropy: 5.84) is also very close to MS in entropy. It is the PCA (entropy: 6.36) which is comparatively far from MS but still closer to MS than to PAN.

The entropy values rank the fused images as PCA>WT+IHS>IHS in accordance with their closeness to the PAN. This means that PCA is sharper than other two fused images, which is contradictory to the findings of the visual analysis that WT+IHS is sharper. Hence, despite the above analysis, it is not possible to arrive at any plausible conclusion with regard to the usefulness of entropy in classification, because one of the fused images- the IHS, which is expected to show higher entropy, exhibits much lower entropy than the original MS image.

To define the closeness between two images, Correlation Coefficient is used which ranges from –1 to +1(Coefficient +1 indicates two images are very close and -1 indicates that two images are opposite to each). Hence, if the correlation values are closer then it means that the spectral quality of the fused image is very good. In this quantitative test, the WT+IHS scored high and stood first with a diagonal sum correlation coefficient of 2.36, PCA the second (2.13), and IHS the third (2.03). The result conveys that the IHS method shows the most obvious colour distortion. The PCA method shows the second obvious colour distortion and the WT+IHS method shows slight colour distortion. It is interesting to note that the WT+IHS is able to retain the higher spectral information of the MS bands by sacrificing higher spatial information; vice-versa in case of IHS. Correlation coefficients of different bands are shown in fig 5.

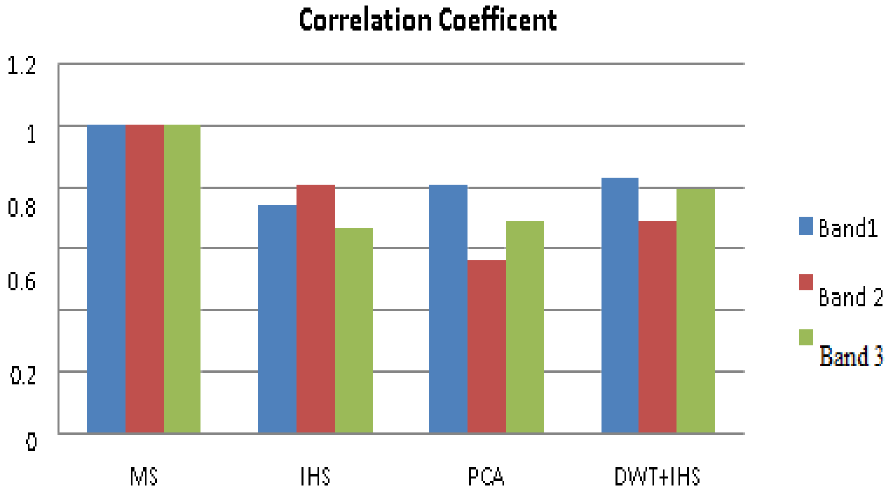

Fig 5 .Correlation coefficient of bands of the fused images and MS

Conclusion

The fused images are ranked as PCA (2.69) >BT (2.54) >MT (2.48) according to the diagonal average of the inter-correlation coefficients between all the three bands of fused images and the corresponding bands of MS image. At the same time, it is can be noted that the average of the correlation coefficients of three bands of the three fused images with panchromatic band computed for five broad LU/ LC features of the semi urban area ranks the images in the order of MT (2.86) > BT (2.81) > PCA (2.30). When the histogram was studied to compute the mean, thereby the average band brightness on comparison with MS bands, the fusion techniques are found to follow the order PCA> BT> MT. A closer visual look reveals that the BT fused image is sharper than the PCA and MT; and MT stands low in this quality. The entropy values ranked the fused images as PCA>BT>MT.

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