Scientific Journal of Impact Factor(SJIF): 3.134

e-ISSN(O): 2348-4470
p-ISSN(P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 2,Issue 4, April -2015

An IHS based Image Fusion over Satellite Images

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Abstract—*Image fusion is the process of combining relevant information from two or more images into a single image. The resulting image will be more informative than any of the input images. Image fusion of Multispectral image and panchromatic image is called as Pan-sharpening. Pan-sharpening combines a low-resolution color multispectral image with a high-resolution grayscale panchromatic image to create a high-resolution fused color image. "Pan Sharpening" is shorthand for "Panchromatic (PAN) sharpening". It means using a panchromatic (single band) image to "sharpen" a multispectral image. In this sense, to "sharpen" means to increase the spatial resolution of a multispectral image. A multispectral image contains a higher degree of spectral resolution than a panchromatic image, while often a panchromatic image will have a higher spatial resolution than a multispectral image. The Intensity-Hue-Saturation (IHS) method is a popular pan-sharpening method used for its efficiency and high spatial resolution. However, the final image produced experiences spectral distortion (Color distortion). In this paper, we introduce IHS methods with modifications to improve the spectral quality of the image. This paper explains the IHS, GIHS, AIHS and EAIHS methods for quality fusion techniques. The quality of the fusion will be decided by the parameters CC, RMSE, RASE, ERGAS,SAM, UIQI and SC.*

Index terms —*Image Fusion, Multispectral image (MS), Panchromatic image (PAN), Pan-sharpening, IHS Transform, Color distortion*

I. INTRODUCTION

Pan-sharpening is a shorthand for panchromatic (PAN) sharpening. It indicates using a pan image to sharpen a multispectral (MS) image. In this sense, to sharpen means to increase the spatial resolution of an MS image. Therefore, the goal of pan-sharpening is to combine the high spatial resolution of the pan image with the precise spectral information of the MS image.

Pan-sharpening algorithms depend on the input images being co-registered, because they all perform operations on corresponding pixels in both images. They all do something with the MS pixel and the pan pixels to create new pixels. If the images are not co-registered, the processing will use the wrong pixels, not the corresponding ones, and the result will not look natural. In addition, the MS data is resampled into the same spatial reference and grid as the pan data, using nearest neighbor, bilinear, or cubic convolution techniques.

A ground-truth usually is not available to evaluate the efficiency of a pan-sharpening technique. Therefore, quality assessment should refer to the goals of the fusion process [1]. The most straightforward objective is image analysis, but also such automated tasks as feature extraction and segmentation or classification have been found. In remote sensing application the image fusion takes important role to fuse the images. The fusion techniques will be decided based on the images which are going to be fused, because the sensors are having different capturing methods. The purpose of fusing those two images is to obtain the high resolution MS images which help the researchers to extract the information from their region of interest.

The multispectral image lacks high spatial quality and the panchromatic image has low spectral quality. Due to these restrictions, many pan-sharpening methods have been created to fuse the two images together to obtain an image with high spectral and high spatial resolutions. A few popular pan-sharpening methods are: IHS [2], PCA-based image fusion [7], Wavelet-based image fusion [7] [14], Brovey transform [2] and P+XS [12]. Each method experiences a trade-off between spectral and spatial quality. Researchers have created variants of these methods to improve their spectral and spatial quality. IHS based methods are often used due to their simple computation, high spatial resolution and efficiency. The fused image results in high spatial resolution and low spectral resolution. In this paper, we introduce IHS methods with modifications to improve the spectral quality of the image.

II. IHS FUSION AND MODIFICATION

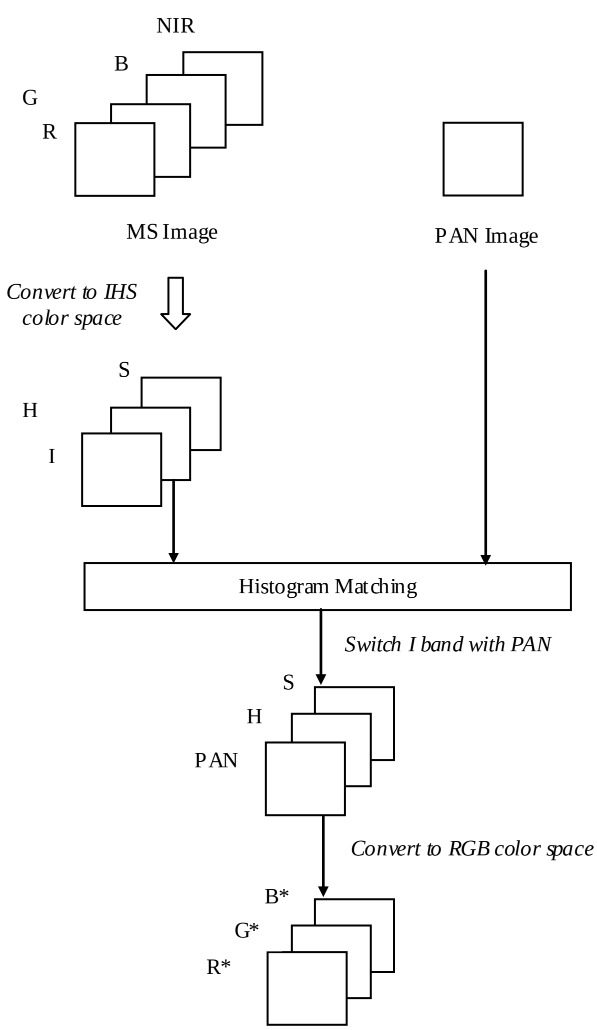
A. IHS Transform:

This is one of the most used methods by many researchers for fusing Panchromatic and Multispectral images. In IHS fusion method the IHS (Intensity, Hue and Saturation) space are converted from the Red, Green and Blue (RGB) space of the Multispectral image. The intensity component I is replaced by the PAN. Then the reverse transform is applied to get RGB image as an output.

The standard fusion method of IHS technique is as follows
1. Read the PAN and MS images as inputs
2. Resize the MS image based on the PAN size
3. Transform RGB components to IHS componetnts
4. Modify the PAN image with respect to the MS image by using histogram matching of PAN image with Intensity level of MS imageMatching the histograms of the PAN image and MS bands will minimize brightness mismatching during the fusion process, which may help to reduce the spectral distortion in the pansharpened image. This method modifies the value of the PAN image as[2],

$$PAN = \frac{\sigma_i}{\sigma_p}\left[P - \mu_p\right] + \mu_i$$

where, σ_i = Standard deviation of Intensity component
σ_p = Standard deviation of PAN Image
μ_p = Mean of PAN image
μ_i = Mean of Intensity component
5. Intensity component replaced by the PAN
6. Reverse transform will obtain high resolution MS image



Fused image

Fig 1 IHS fusion principle

In IHS-based fusion, the transformation of RGB to IHS will be based on the following formulas.

RGB-IHS Transform:

$$\begin{bmatrix} I \\ V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} \frac{1}{3} & \frac{1}{3} & \frac{1}{3} \\ \frac{-\sqrt{2}}{6} & \frac{-\sqrt{2}}{6} & \frac{2\sqrt{2}}{6} \\ \frac{1}{\sqrt{2}} & \frac{-1}{\sqrt{2}} & 0 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}$$

Where,

$$I = \frac{R + G + B}{3}$$

$$H = \tan^{-1}\left(\frac{V_1}{V_2}\right)$$

$$S = \sqrt{V_1^2 + V_2^2}$$

Replace the intensity with Pan Band:

$$\begin{bmatrix} I \\ V_1 \\ V_2 \end{bmatrix} \Rightarrow \begin{bmatrix} Pan \\ V_1 \\ V_2 \end{bmatrix}$$

Inverse Transform (IHS-RGB):

$$\begin{bmatrix} R_{new} \\ G_{new} \\ B_{new} \end{bmatrix} = \begin{bmatrix} 1 & \frac{-1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & \frac{-1}{\sqrt{2}} & \frac{-1}{\sqrt{2}} \\ 1 & \sqrt{2} & 0 \end{bmatrix} \begin{bmatrix} Pan \\ V_1 \\ V_2 \end{bmatrix}$$

$$\begin{bmatrix} R_{new} \\ G_{new} \\ B_{new} \end{bmatrix} = \begin{bmatrix} 1 & \frac{-1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & \frac{-1}{\sqrt{2}} & \frac{-1}{\sqrt{2}} \\ 1 & \sqrt{2} & 0 \end{bmatrix} \begin{bmatrix} I + (Pan - I) \\ V_1 \\ V_2 \end{bmatrix}$$

$$= \begin{bmatrix} 1 & \frac{-1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & \frac{-1}{\sqrt{2}} & \frac{-1}{\sqrt{2}} \\ 1 & \sqrt{2} & 0 \end{bmatrix} \begin{bmatrix} I + \delta \\ V_1 \\ V_2 \end{bmatrix}$$

$$= \begin{bmatrix} R + \delta \\ G + \delta \\ B + \delta \end{bmatrix}$$

Where, $\delta = Pan - I$

B. GIHS Transform (Generalized IHS):

IHS transform contain only the three-band images a linear transformation used in the enrichment. Multispectral image contains four or more bands. To make this kind of enrichment in satellite images article generalized IHS (GIHS) method has been proposed [10].According to this method RGB-IHS transform will be done by this formulas:

$$\begin{bmatrix} R' \\ G' \\ B' \\ NIR' \end{bmatrix} = \begin{bmatrix} R + \delta' \\ G + \delta' \\ B + \delta' \\ NIR + \delta' \end{bmatrix}$$

$$\delta' = Pan - I'$$

$$= Pan - \left(\frac{R + G + B + NIR}{4}\right)$$

C. AIHS Transform (Adaptive IHS):

In order to minimize spectral distortion in the IHS pan-sharpened image, we propose a new modification of the IHS that varies the manner the intensity band is calculated depending on the initial multispectral and panchromatic images. To minimize spectral distortion the intensity band should approximate the panchromatic image as closely as possible. Therefore in thisadaptive IHS method we want to determine the coefficients α that best approximate [8].We want to approximate the panchromatic image as a linear combination of the multispectral bands:

$$PAN \simeq I = \alpha_1 M_1 + \alpha_2 M_2 + \alpha_3 M_3 + \alpha_4 M_4$$

Where, value of α is choose as per the image adaptive coefficient from the [13].Calculating the coefficients in this manner increases the spectral quality of the images because it generates coefficients according to the original data, and maintains the good spatial quality of the IHS method.

D. EAIHS Transform (Edge Adaptive IHS):

In this method, we want to transfer the edges from the panchromatic image to the fused image. This approach extracts the edges from the panchromatic image, and where there are edges we impose the IHS method and on the locations where there are no edges we simply put the multispectral image. The fused multi-channel image F is formed by the new formula:

$$F_i = M_i + h(x)\,(P - I)$$

Where, h(x) is an edge detecting function. We want h(x) to equal 1 one on edges and equal to zero off edges. The extracted edge can be obtained using standard edge detection methods such as Canny detector [8]. The edges of thepanchromatic image are extracted using an exponential edge detector.

$$h(x) = exp\left(\frac{-\lambda}{|\nabla P|^4 + \mathcal{E}}\right)$$

Where, ∇P is the gradient of the panchromatic image, λ is a parameter indicating how large the gradient should be in order to be an edge and controls the smoothness of the image, and Ɛ is a small value that enforces a nonzero denominator [8]. The values that proved successful are $\lambda = 10^{-9}$and $\mathcal{E} = 10^{-10}$.Using these values and combining the edge detection with the original IHS increases the spectral resolution significantly.

III. QUALITY ASSESSMENT PARAMETER

A. Relative Dimensionless Global Error in Synthesis (ERGAS):

The ERGAS calculates the amount of spectral and radiometric distortions in the image [6]. The formula for the ERGAS is

$$ERGAS = 100\,\frac{h}{l}\sqrt{\frac{1}{N}\sum_{n=1}^{N}\left[\frac{RMSE\,(n)}{\mu(n)}\right]^2}$$

Where, h/l is the ratio between pixel sizes of the PAN and MS images,μ(n) is the mean of the nth band, and N is the number of bands.

B. Root mean square error (RMSE):

The RMSE between each band of the reference and the pan-sharpened image measures the changes in radiance of the pixel values. RMSE is a very good indicator of the spectral quality when it considered along homogeneous regions in the image. RMSE should be as close to 0 as possible. The formula of RMSE [2] is

$$RMSE = \sqrt{\frac{1}{m * n} \sum_{i=1}^{m} \sum_{j=1}^{n} (F(i,j) - MS(i,j))^2}$$

Where, F is the high-resolution fused image, MS is the original multispectral image, and m × n is the image size.

C. Relative average spectral error (RASE):

The RASE characterizes the average performance in the spectral bands [4]:

$$RASE = \frac{100}{M} \sqrt{\frac{1}{N} \sum_{i=1}^{N} \left(RMSE(B_i)\right)^2}$$

Where, M is the mean radiance of the N spectral bands $(B_i)$of the original MS image.

D. Correlation Coefficient (CC):

CC is used for comparing image and expresses the spectral information contained in the fused image depending on the original MS image [14].

$$CC = \frac{\sum_{i=1}^{n}(X_i - \bar{X})}{\sqrt{\sum_{i=1}^{n}(X_i - \bar{X})^2}\ \sqrt{\sum_{i=1}^{n}(Y_i - \bar{Y})^2}}$$

Where, $\bar{X}$ and $\bar{Y}$ arestand for the mean values of the corresponding data set, and CC is calculated globally for the entire image

E. A Universal Image Quality Index(Q- average):

UIQI can measure the local relationship, luminance, and contrast between two images. Assuming that x denotes the reference and y denotes the test image, UIQI is defined as [5]:

$$Q_{ave} = \frac{4\ \sigma_{xy}\ \overline{xy}}{\left(\sigma_x{}^2 + \sigma_y{}^2\right)[(\bar{x})^2 + (\bar{y})^2]}$$

Where, σ_{xy} denotes the covariance between x and y

$\sigma_x$andσ_y represent the variances of x and y, respectively;

$\bar{x}$and$\bar{y}$ are the means of x and y, respectively

F. Spectral Angle Mapper (SAM):

SAM denotes the absolute value of the angle between two spectral vectors in two image pairs, whose elements are the values of the pixels for the different bands of the fuse image and the MS image at each image location. SAM is measured either in degrees or in radians and is usually averaged over the whole image to yield a global measurement of spectral distortion.The SAM takes the arccosine of the dot product between two spectral vectors [3]:

$$SAM(V, \hat{V}) = \frac{\cos^{-1} < V, \hat{V} >}{\|V\|_2 \cdot \|\hat{V}\|_2}$$

Which can be written as,

$$SAM(v, w) = \cos^{-1}\left(\frac{\sum_{i=1}^{L} v_i w_i}{\sqrt{\sum_{i=1}^{L} v_i{}^2}\ \sqrt{\sum_{i=1}^{L} w_i{}^2}}\right)$$

Small angles indicate high similarity, and high angles indicate low similarity.

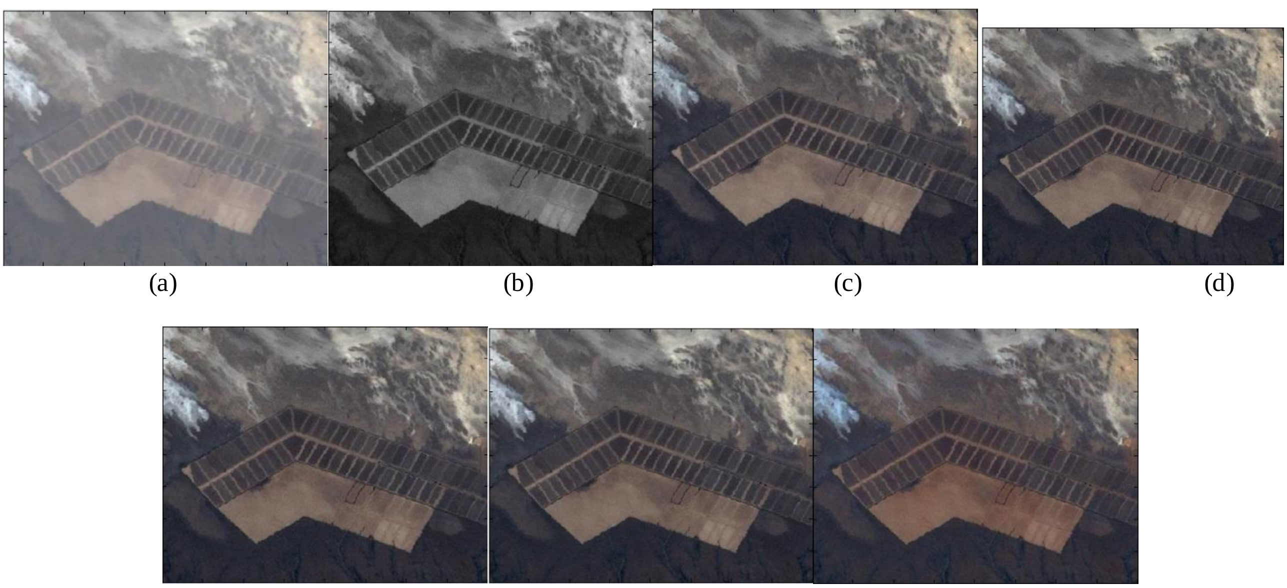
G. Spatial correlation:

To judge the spatial quality of the pan-sharpened image, we have used the method proposed by [14]. First the pan and the high-frequency MS images are filtered using a Laplacian filter:

$$\text{Laplacian filter} = \begin{bmatrix} -1 & -1 & -1 \\ -1 & +8 & -1 \\ -1 & -1 & -1 \end{bmatrix}$$

IV. CONCLUSION

The IHS pan-sharpening method gives good spatial quality and is a commonly used algorithm for its speed and simplicity but we can't get the spectral quality high. To improve its spectral quality we proposed a techniques with modification in IHS: GIHS, AIHS and EAIHS. The IHS fusion methods give the quality output images. But this method having the same problem which is color distortion. The change in color during the fusion is called as color distortion. IHS using only three bands. GIHS is the advance than the IHS which use the four bands (red, green, blue and NIR). GIHS having near infrared band which is use for the some spectral observation than the IHS transform. InAIHS weighted adaptive coefficients are added. And EAIHS is having edge adaptive parameter which are added into A IHS. The quality of the fusion will be measured by the statistics of the fused image properties.The performance evaluation metrics confirmed the competence of the edge adaptive IHS method.



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

(e) (f) (g)

Fig. 2. Simulated pan-sharpening methods. (a) Low-resolution MS image. (b) High-resolution PAN image.(c) Result of the IHS-based method.
(d) Result of the GIHS method. (e) Result of the AIHS method. (f) Result of the EAIHS method. (g) Result of the PCA method

(A rural LANDSAT-7 scene in Sioux Falls, SD. Source: USGS, www.americaview.org)[9]

Methods	**CC (0)**	**RMSE (0)**	**RASE (0)**	**ERGAS (0)**	**Q-ave (1)**	**SAM (0)**	**SC (1)**
HIS	0.005643	5.5319	5.2281	1.2832	0.74915	0.19845	**0.99097**
GIHS	0.0025398	4.8164	4.5519	1.154	**0.99905**	0.18954	0.98982
AIHS	0.0006966	4.5161	4.2681	1.0607	0.9982	0.057631	0.99014
EAIHS	**0.0006280**	**4.2767**	**4.0418**	**1.0045**	0.99842	**0.049924**	0.96877
PCA	0.11153	10.9851	10.3819	2.57	0.98592	0.46914	0.93416

Table I. Quality assessment parameter of methods

ACKNOWLEDGMENTS

The author would like to thank Professor PunitRaninga for hisadvice and assistance.

REFERENCES

[1] Wald, L., 1999. Some terms of reference in data fusion. IEEE Transaction on Geoscience and Remote Sensing 37 (3), 1190–1193.
[2] IsraaAmro, Javier Mateos, Miguel Vega, Rafael Molina and Aggelos K Katsaggelos, “A survey of classical methods and new trends in pansharpening of multispectral images”,EURASIP Journal on Advances in Signal Processing 2011, 2011:79
[3] MiloudChikr El-Mezouar, NasreddineTaleb, KidiyoKpalma, and Joseph Ronsin, “An IHS-Based Fusion for Color Distortion Reduction and Vegetation Enhancement in IKONOS Imagery”, IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 49, NO. 5, MAY 2011
[4] Ranchin, T., Wald, L., 2000. Fusion of high spatial and spectral resolution images: The ARSIS concept and its implementation. Photogrammetric Engineering and Remote Sensing 66 (1), 49–61.
[5] Xiran Zhou b, Jun Liu a,⇑, Shuguang Liu a, Lei Cao a,c, Qiming Zhou d, Huawen Huang a, “A GIHS-based spectral preservation fusion method for remote sensing images using edge restored spectral modulation”, ISPRS Journal of Photogrammetry and Remote Sensing 88 (2014) 16–27
[6] Wald, L., 2000. Quality of high resolution synthesized images: Is there a simple criterion? In: Proc. of the third conference Fusion of Earth data: Merging point measurements, raster maps and remotely sensed images. Sophia Antipolis,France. 26–28 January. 6 p.
[7] Pohl, C. and Van Genderen, J. L., 1998, Multisensor Image Fusion in Remote Sensing: Concepts, Methods and
[8] Kosesoy, I.;Tepecik, A.; Cetin, M.; Mesut, A., “A Comparative Analysis of Image Fusion Methods.” IEEE Signal Processing and Communications Applications Conference (SIU), 2012 20th
[9] SheidaRahmani, Melissa Strait, Daria Merkurjev, Michael Moeller, Todd Wittman, “An Adaptive IHS Pan-sharpening Method”, IEEE GEOSCIENCE AND REMOTE SENSING LETTERS, 2010
[10] T.-M. Tu, S.-C. Su, H.-C. Shyu, and P. S. Huang, “A new look at IHS-like image fusion methods,” Inform. Fusion, vol. 2, pp. 177–186, 2001
[11] Tu, T.M., P.S. Huang, C.L. Hung, and C.P. Chang. "A Fast Intensity-Hue Saturation Fusion Technique with Spectral Adjustment for IKONOS Imagery." IEEE Geoscience and Remote Sensing Letters 1 (2004): 309-312
[12] Ze-ming Zhou, Ping-lv Yang, Yuan-xiang Li, Wen Yin, Lin Jiang, “IHS AND VARIATIONAL METHODS FOR PAN-SHARPENING OF VERY HIGH +RESOLUTION IMAGERY”, IGARSS 2013
[13] M. Choi, H. Kim, N.I. Cho and H.O. Kim. “An Improved Intensity-Hue-Saturation Method for IKONOS Image Fusion.” International Journal of Remote Sensing. 2008.
[14] Zhou, J., Civco, D.L., Silander, J.A., 1998. A wavelet transform method to merge Landsat TM and SPOT panchromatic data. International Journal of Remote Sensing 19 (4), 743–757.