International Journal of Computer Applications (0975 – 8887)
National Conference on Recent Trends in Computer Science & Engineering (MEDHA 2015)

Additive Wavelet based Image Fusion using Improved Nonlinear IHS Transformation

Mahesh P. Chakkarwar
M. Tech. Scholar
GCOE, Amravati

A. V. Deorankar
Assistant Professor, Head of Information Technology
GCOE, Amravati

Vrushali A. Chakkarwar
Assistant Professor
GCOE, Aurangabad

ABSTRACT

Image fusion is maintaining the spectral quality of the Multispectral (MS) image while retaining the spatial quality of the panchromatic image (PAN) image. Image fusion is a good alternative for increasing interpretability of MS image by inserting spatial information from PAN image to MS image. For the image fusion traditional IHS (intensity, hue and saturation) have been used, but this leads to out of gamut problem. Out of gamut leads to color distortion and contrast reduction in the resultant fused image. In this paper improved nonlinear IHS image fusion is used, which solves the out of gamut problem. But, due to the large intensity differences between PAN image and MS image, leads to color distortion. This paper proposes and implemented adding spatial information from PAN image to MS image rather than conventional intensity substitution. DWT (Discrete Wavelet Transformation) is used for getting spatial information from PAN image that will be added to MS image. This solves the color distortion due to large intensity difference between MS and PAN image and preserves spectral quality of MS image in the fused image.

General Terms

Image fusion, land cover classification, enhancement of satellite multispectral images.

Keywords

IHS, HIS, nonlinear IHS, wavelet.

1. INTRODUCTION

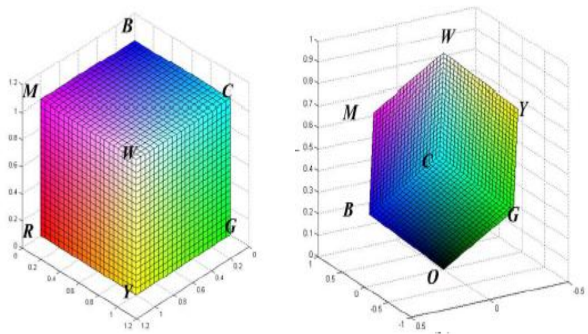
Image fusion is nothing but interpretability of MS image by introducing spatial information from the PAN image. The color of information is nothing but reflection of solar rays from the target object while brightness of PAN image is a function of shape, roughness, material of object and geometry of the target object. PAN images are difficult to interpret, but PAN image may contain useful information that cannot be found in the MS image. From the above perspective, we can say PAN images are useful for feature detection, object classification etc. It means that PAN images have high spatial information while MS image have high spectral information. The objective of image fusion is to get images which have qualities of both MS image and PAN image. This paper introduces alternate method of image fusion for fusing high spatial PAN image and low spectral resolution MS image by using improved nonlinear IHS transformation and wavelet decomposition.

1.1 Traditional IHS image fusion

PAN image stores the spatial information in the single intensity component of the image. To manipulate the individual component of MS image like intensity, hue and saturation, MS image is transformed into IHS image using IHS transformation. IHS transformation is done using two methods are as fallows;

1.2 Linear IHS transformation

Linear IHS transformation based on RGB cube is nothing but the direct color shifting in the RGB color space [1]is visually shown as below;



a) b)

Fig. 1 a) RGB cube b) Linear IHS transformation based on RGB cube.

Linear IHS transformation in the RGB cube is nothing but the direct color shifting [1]. The graphical model for linear IHS color space is shown in fig. 3(a).

The linear RGB to HIS conversion and its inverse is given as fallows [2];

1.2.1 RGB to IHS Conversion

$$[i\ h\ s]^T = A \times [r\ g\ b]^T$$

Where,

$$A = \begin{bmatrix} 1/3 & 1/3 & 1/3 \\ -\sqrt{2}/6 & -\sqrt{2}/6 & 2\sqrt{2}/6 \\ 1/\sqrt{2} & -1/\sqrt{2} & 0 \end{bmatrix}$$

1.2.2 IHS to RGB conversion

$$[r'\,g'\,b']^T = B \times [i'\,h'\,s']^T$$

Where,

$$B = \begin{bmatrix} 1 & -1/\sqrt{2} & 1/\sqrt{2} \\ 1 & -1/\sqrt{2} & -1/\sqrt{2} \\ 1 & \sqrt{2} & 0 \end{bmatrix}$$

By the above transformations, the effect of conducting intensity substitution $i' = i + \delta$ in the IHS space may be shown to be just a direct color shifting in the originalRGB space as follows [1]:

$$[r'\,g'\,b']^T = B \times [i'\,h'\,s']^T = B \times [i + \delta\ h\ s]^T = [r\ g\ b]^T + [\delta\ \delta\ \delta]^T$$

1.3 Nonlinear IHS transformation

Nonlinear IHS space is nothing but cylindrical IHS model, center axis represents the Intensity component, distance between the center axis and edge of the cylinder i.e. radius of cylinder representssaturation and arc angle represents the hue. Intensity represents the brightness of a color, saturation represents the purity of the color defines the radius of cylinder and hue represents average wavelength of color defines the angle of the cylinder.

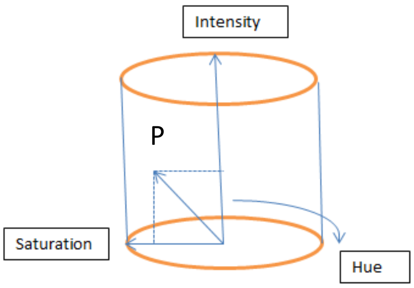


Fig. 2 Nonlinear Cylindrical IHS Model

Nonlinear IHS transformation in the RGB cube is nothing but the scaling operation [1]. The graphical model for nonlinear IHS color space is shown in fig. 3(b). The nonlinear IHS transformation also called HSI color transformation is defined as fallows [3];

1.3.1 RGB to HSI Conversion

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

$$a = \frac{(2B - G - R)/2}{\sqrt{(B-G)^2 + (B-R)(G-R)}}$$

$$H = \begin{cases} \cos^{-1}(a) & if\ \ G \geq R \\ 2\pi - \cos^{-1}(a) & if\ G < R \end{cases}$$

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

1.3.2 HSI to RGB Conversion

% SECTION RG ($0° \leq H < 120°$)

$$B = I(1-S);$$
$$R = I\left[\frac{SCOS(H)}{COS(60° - H)}\right];$$
$$G = 3I - (R+B);$$

% SECTION GB ($120° \leq H < 240°$)

$$R = I(1-S);$$
$$G = I\left[1 + \frac{SCOS(H)}{COS(60° - H)}\right];$$
$$B = 3I - (R+G);$$

% SECTION BR ($240° \leq H < 360°$)

$$G = I(1-S);$$
$$B = I\left[1 + \frac{SCOS(H)}{COS(60° - H)}\right];$$
$$B = 3I - (R+G);$$

2. GAMUT PROBLEM

When RGB image is transformed to IHS color space using IHS transformation, some pixelshas values greater than one known as out of gamut pixels. When the intensity component in IHS model replaced by the PAN image and when it is back transformed to RGB image the pixels falls out of RGB cube. This out of gamut pixel leads to contrast reduction and color distortion. This out of gamut problem is solved using improved nonlinear IHS transformation (iNIHS) is given as below[1];

- The boundary surface BS_{iNIHS} two halves is given as;
  - $i = \frac{2}{3} - \frac{\|h_{mod\ 120} - 60\|}{180}$;
  - The algorithm for RGB to iNIHS is as fallows;

    $if\ i_c \leq \frac{2}{3} - \frac{\|h_{mod\ 120} - 60\|}{180}$ then

    % Pixel C is in H_{LOWER}

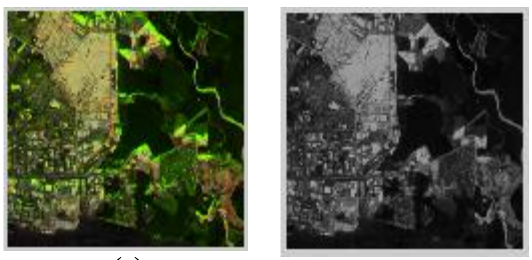
    % RGB to IHS transformation

    $else$

    % Pixel C is in H_{UPPER}

    % CMY to IHS transformation

The gamut problem is visually analyzed both using nonlinear IHS transformation and improved nonlinear IHS transformation as shown below;



(a) (b)

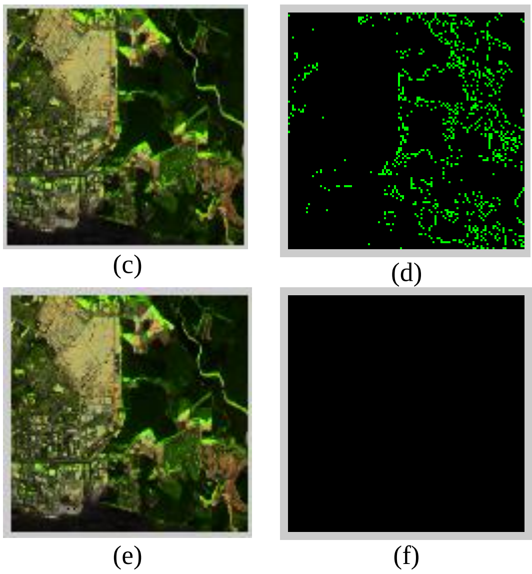


Fig. 3 a) Multispectral MS image b) Panchromatic PAN image c) Fusion of MS and PAN using IHS Transformation d) Gamut Pixels in the image using IHS Transformation e) Gamut Pixels in the image using iNIHS Transformation.

Though the out of gamut problem is solved using improved nonlinear IHS transformation (iNIHS) but when intensity component from iNIHS is replaced by the PAN image having large intensity difference leads to color distortion. So, instead of direct intensity substitution from MS image, only spatial details from the PAN image are added into the MS image. This paper illustrated adding spatial details from PAN image to MS image, and results are shown both visually and quantitatively.

3. PROPOSED METHOD

For getting spatial details from PAN image, Discrete Wavelet Transformation (DWT) is used. DWT results spatial details in vertical, horizontal and diagonal wavelet planes. These details are added to Intensity component of MS image.

The steps for merging IKONOS images using additive wavelet using iNIHS transformationare as fallows [4]:

1) Apply the iNIHS transform to the RGB composition of the multispectral image. This transformation separates the spatial information of the multispectral image into the Intensity component.
2) Generate a new panchromatic image, whose histogram matches the histogram of the Intensity image.
3) Apply wavelet decomposition algorithm to the Intensity image and to the 'histogram-matched' panchromatic one. Both second level decompositions are computed using the Daubechies four-coefficient wavelet basis. Extract the wavelet coefficients that pick up the horizontal, vertical and diagonal spatial details present in the panchromatic image and missing in the multispectral image.
4) Add this spatial detail information into the Intensity image,by adding the wavelet coefficients of the PAN image to those of multispectral, applying the inverse wavelet transform.

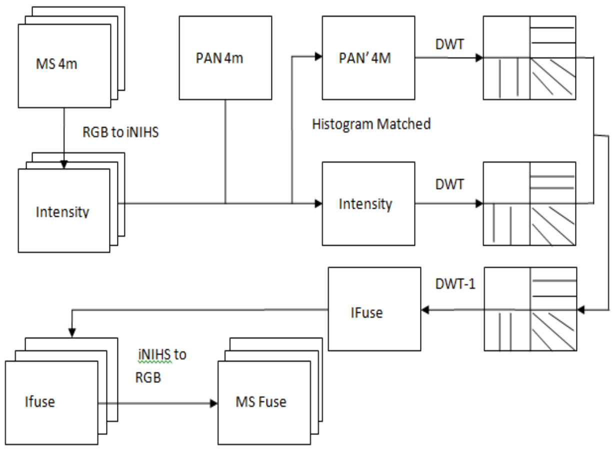


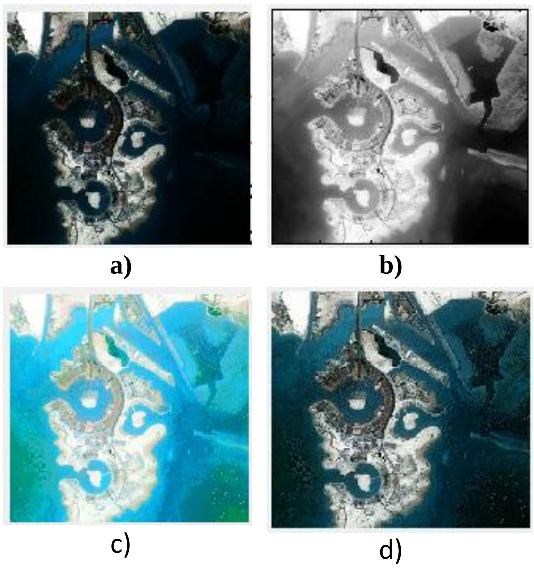
Fig. 4 Additive Wavelet Image Fusion using improved nonlinear IHS transformation

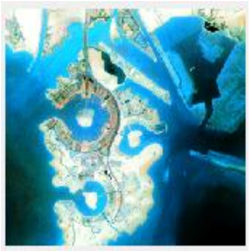
4. EXPERIMENTAL RESULTS AND DISCUSSION

4.1 Visual Analysis

The multispectral images are downloaded from IKONOS. Artificial dataset for image fusion i.e. multispectral (MS) and panchromatic (PAN) images are derived from given satellite multispectral image. The generation of dataset for image fusion is as fallows;

1) Let the given satellite image be I.
2) Transform the image Iinto gray image G.
3) Equalize the histogram of image G, and take the result as PAN image.
4) Down-sample I to its original resolution to get generated MS image I'.
5) Darken I' or brighten G so that the intensity values of PAN (G) image are higher than the MS (I').
6) Image fusion is carried out on PAN (G) and MS (I') image.





e)

f)

Fig. 5 a) MS image b) PAN image c) Image fusion of a and b using IHS intensity substitution d) Image Fusion of a and b using IHS wavelet additive e) Image fusion of a and b using iNIHS intensity substitution f) Image fusion of a and b using iNIHS wavelet additive

4.2 Quantitative Analysis:

The quantitative analysis of methods of image fusion is carried out by the measures Root Mean Square Error (RMSE), Correlation Coefficient (CC).

The RMSE between original MS image and fused image is given as;

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(xi - yi)^2}{n}}$$

The Correlation Coefficient between MS image and result of image fusion is given as;

$$r = \frac{\sum_i (xi - xm)(yi - ym)}{\sqrt{\sum_i (xi - xm)^2}\sqrt{\sum_i (xi - xm)^2}}$$

The quantitative results of Image fusion using IHS transformation and iNIHS transformation by the Additive wavelet method and intensity Substitution and their comparison is shown as below;

Table 1 Quantitative Analysis of Image for two dataset each contains pair of images.

Sr. No.	Transformation	Fusion Method	Dataset	RMSE	CC
	IHS Trans-formation	Intensity Substitution	1	0.394	0.752
			2	0.25	0.928
		Additive Wavelet Method	1	0.035	0.99
			2	0.072	0.963
	iNIHS Trans-formation	Intensity Substitution	1	0.29	0.85
			2	0.20	0.98
		Additive Wavelet Method	1	0.024	0.99
			2	0.052	0.987

5. ABBREVIATIONS

MS: Multispectral image
PAN: Panchromatic image
IHS: Intensity, hue and saturation transform
HSI: Nonlinear intensity, hue and saturation transform
iNIHS: improved nonlinear IHS
RMSE: Root mean square error
R: correlation coefficient

6. CONCLUSION

Image fusion using IHS may incur gamut problem, which is solved using color clipping that leads to contrast reduction and color reduction. Improved nonlinear IHS transformation solves the gamut problem. Though, the gamut problem is solved, due to the large intensity difference between MS and PAN image leads to color distortion. This, problem is solved using adding only spatial information from PAN image to MS image instead of directly replacing intensity from MS image by PAN. The results are analyzed both visually and quantitatively using Root Mean Square Error (RMSE) and Correlation Coefficient (CC). Future work will related to sharpening MS image without image fusion techniques have been used so far.

7. REFERENCES

[1] Chun-Liang Chien and Wen-Hsiang Tsai, “Image Fusion With No Gamut Problem by Improved Nonlinear IHS Transforms for Remote Sensing”, IEEE Transactions on Geoscience And Remote Sensing, Vol. 52, No. 1, January 2014.

[2] T. M. Tu, S. C. Su, H. C. Shyu, and P. S. Huang, “A new look at IHS-like image fusionmethods,” *Inf. Fusion*, vol. 2, no. 3, pp. 177–186, Sep. 2001.

[3] R. C. Gonzalez and R. E. Woods, *Digital Image Processing*. Upper Saddle River, NJ, USA: Prentice-Hall, 2007.

[4] M. González-Audícana, X. Otazu, O. Fors, and A. Seco, “Comparison between Mallat’s and the ‘a trous’ Discrete wavelet transform based algorithms for the fusion of multispectral and panchromatic images,” *Int. J.Remote Sens.*, vol. 26, no. 3, pp. 595–614, Feb. 2005.