Fusion of Panchromatic and Multispectral Image with no Gamut

Mahesh P. Chakkarwar[1]
Computer Science and Engineering
Government College Of Engineering, Amravati
Amravati, India
Maheshchakkarwar21@gmail.com

Prof A. V. Deorankar[2]
Computer Science and Engineering
Government College Of Engineering, Amravati
Amravati, India
avdeorankar@gmail.com

Abstract— Satellite with different sensors generates images with different characteristics such as, images with spatial resolution such as panchromatic (PAN) images and images with high spectral resolution such as multispectral (MS) images. But for feature extraction, land cover analysis etc. requires images with high spatial and spectral characteristics. Several image fusion methods have been discovered, but each of the methods generates gamut problem. In this paper gamut problem is analyzed visually, a new model improved nonlinear IHS model is used to solve the gamut problem. This model solves gamut problem occurred during image fusion. We have analyzed HIS and iNIHS (Improved Nonlinear IHS Transformation) visually and quantitatively by using intensity substitution during image fusion. After analysis it comes to know that, due to the large intensity differences between input images MS and PAN, there is color distortion in the image. This paper suggests, rather than intensity substitution while image fusion only the spatial details from the PAN image should be embedded into MS image while image fusion.

Keywords- Image Fusion, Gamut, IHS.

I. INTRODUCTION

Satellites like IKONOS and Quick bird have different sensors which generates images with different resolution. The results of the different remote sensing systems are diverse in spatial, spectral and temporal resolutions. Spatial resolution corresponds to pixel size covering the earth surface. The satellite image is said to be high spatial resolution such as it detects object of size least 0.41m to 4m and it is called low resolution image if it detects object of size, greater than 30m to 1000m called as low resolution image. The pixel size of high and low resolution images is in the following figure;

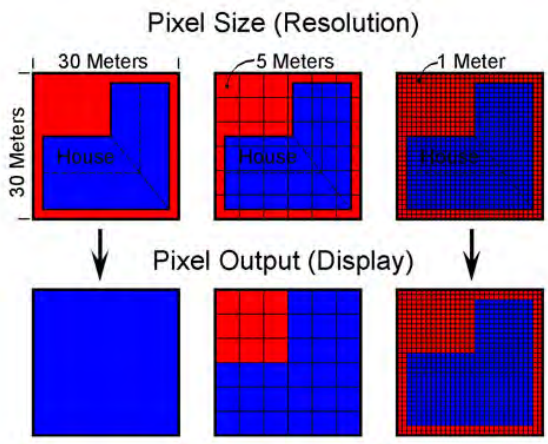


Fig. 1 Pixel of low resolution and high resolution image

Sensors spectral resolution specifies the no. of spectral bands in which sensors collect reflected radiance. But not only the no. of bands is important aspect but the position of bands is also important aspect of spectral resolution. A sensor can generate high resolution spectral images if it has 220 bands, medium spectral resolution if it has 3-15 bands and low spectral resolution if it has less than 3 bands. The different spatial, temporal and spectral resolutions are the limiting factor for the utilization of the satellite image data for different applications.

Due to the technical constraint, satellite's remote sensing system has the relationship such as high spatial resolution associated with low spectral resolution. That means images generated by the satellite sensor with high spectral resolution have low spatial resolution. It is necessary to find compromises between these two types of images i.e. images with high spatial resolution and images with high spectral resolution depends on the application. Another way is to generate images with high spectral and spatial resolution by fusing image with high spatial resolution and image with high spectral resolution.

Different image fusion methods have been proposed till date such as IHS (Intensity, hue saturation), PCA (Principle Component Analysis), Brovey Analysis etc. However, these all the image fusion methods not touched gamut problem occurred while image fusion. Gamut problem is nothing but value of pixel falls out of RGB cube. These all the methods solve the gamut problem using color clipping. This leads to color distortion in the image. This paper visualizes the gamut problem and solves it using improved nonlinear IHS transform.

II. TRADITIONAL IHS IMAGE FUSION METHOD

In the IHS image fusion, each pixel in the RGB cube is transformed into IHS (Intensity, Hue and Saturation) where each component of image such as intensity, hue and saturation can be manipulated intuitively. There are two methods of IHS image fusion such linear IHS image fusion and nonlinear IHS image fusion. The IHS image fusion is shown in the following diagram [3];

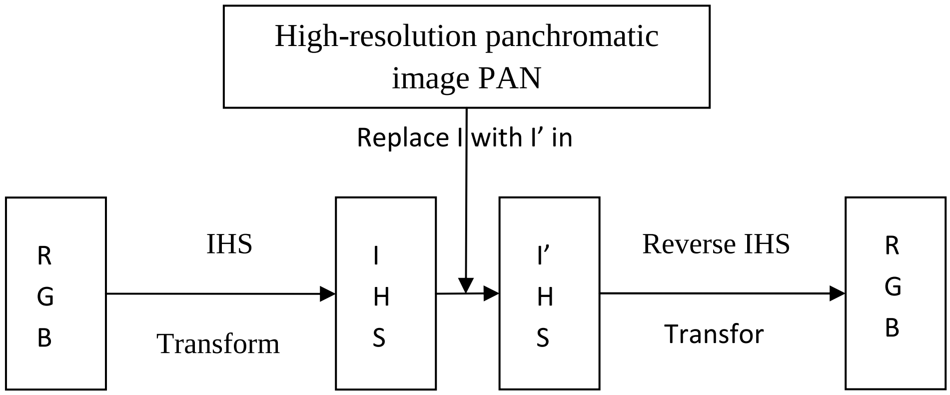
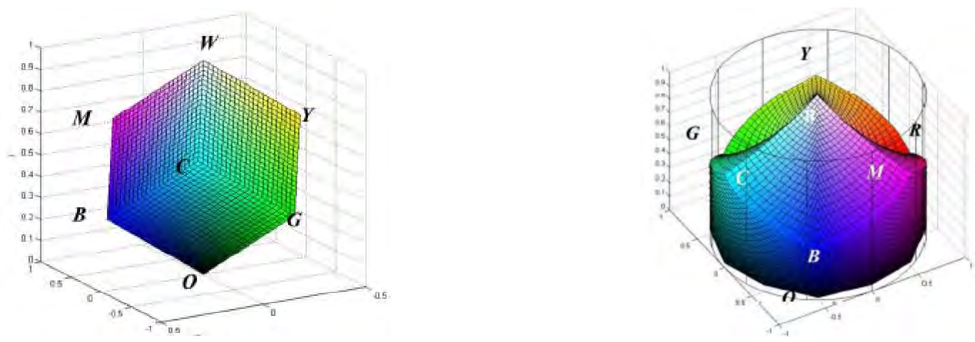


Fig. 2 Illustration of Image Fusion using IHS Transformation using intensity substitution

There are two methods of IHS image fusion; one is linear IHS image fusion and other is nonlinear IHS image fusion also called HSI image fusion. Linear and Nonlinear model derived from RGB cube is shown in the following figure;



(a) (b)

Fig.3 a) Linear IHS model b) Nonlinear IHS model

A. Linear IHS transformation is given as below;

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).

1. RGB to IHS Conversion.

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

Where,

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

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 original RGB space as follows [1]:

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

B. Nonlinear IHS image fusion is given as below;

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 [4];

1. RGB to HSI Conversion

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

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

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

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

2. HIS 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 ($240° \leq H < 360°$)

$G = I(1 - S)$;

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

$B = 3I - (R + G)$;

III. IMPROVED NONLINEAR IHS TRANSFORM

Conversion of RGB to improve nonlinear IHS transformation is defined as fallows [1];

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

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

% Pixel C is in H_{LOWER}

% RGB to IHS transformation

$else$

% Pixel C is in H_{UPPER}

% CMY to IHS transformation

For the lower half of the improved nonlinear IHS model, use the above explained RGB to IHS transformation equations and IHS to RGB equations. And for the upper half that is above the boundary surface, use CMY to IHS transformation, CMY model is given as $[C, M, Y] = [1 - R, 1 - G, 1 - B]$.

IV. EXPERIMENTAL RESULTS AND DISCUSSION

A. Visual Analysis:

The multispectral images are downloaded from Quick Bird. 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 I into 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.

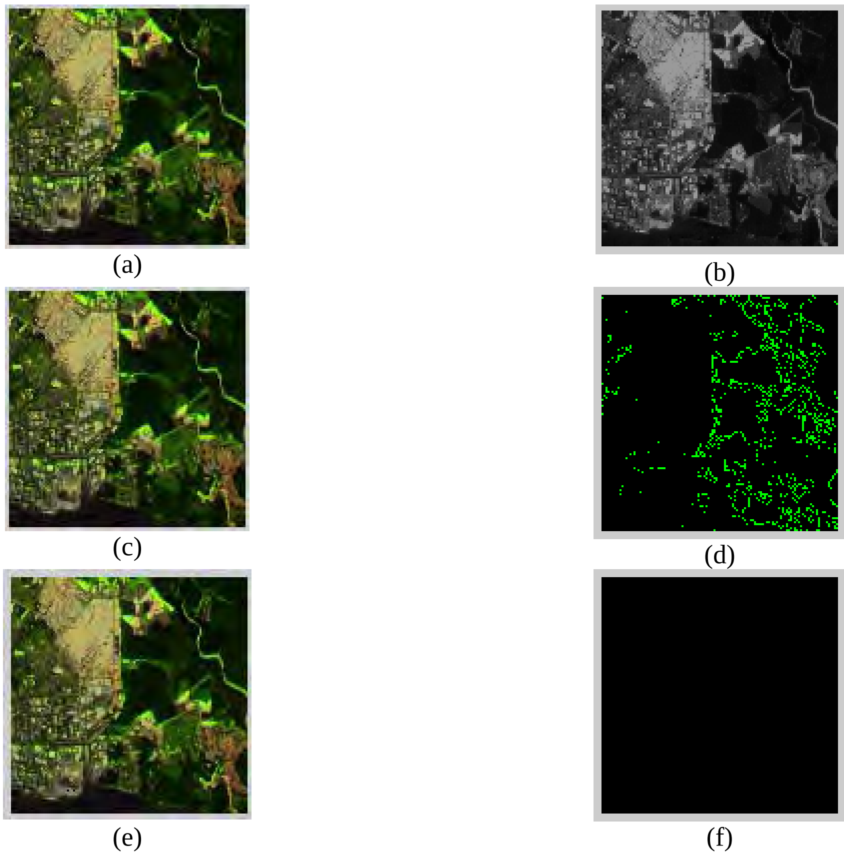


Fig. 4 a) Multispectral MS image b) Panchromatic PAN image c) Fusion of MS and PAN using IHS Transformation d) Gamut Pixels in the image using IHS Transformation e) Gamut Pixels in the image using iNIHS Transformation.

Image fusion is carried out using both nonlinear IHS transformation and improved nonlinear HIS transformation on the Multispectral (MS) image shown in Fig. 4(a) and panchromatic (PAN) image shown in Fig. 4(b). Fusion results of IHS image fusion is shown in Fig. 4(c) and gamut pixels which falls out of RGB cube shown in Fig. 4(d). Improved nonlinear IHS fusion solves the gamut problem, results shown in Fig. 4(e), with no gamut pixels shown in Fig. 4(f).

B. Quantitative Analysis:

The quantitative analysis of methods of image fusion is carried out by the measures Spatial Coefficient (SC),
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 results of the Image fusion are measured using RMSE and Correlation Coefficient is as shown in the following table;

Table 1 Quantitative Results of Image Fusion of given Panchromatic and Multispectral Images

Sr. No	Method	RMSE	CC
1	IHS Transformation	0.113	0.975
	iNIHS Transformation	0.143	0.936
2	IHS Transformation	0.305	0.855
	iNIHS Transformation	0.304	0.841

V. CONCLUSION

Both linear RGB to IHS and nonlinear RGB to IHS used for image fusion leads to gamut problem. These methods solve the gamut problem using color clipping that leads to color distortion and contrast reduction. In this paper gamut problem is analyzed visually and solved using improved nonlinear IHS transformation. Though the gamut problem is solved, there is color distortion when there is a large intensity difference between the multispectral image and panchromatic image. This paper proposes, rather than direct intensity substitution only the spatial information from the PAN image is injected into the multispectral image. This paper proposes wavelet based image fusion using improved nonlinear IHS transformation. The method is described as below;

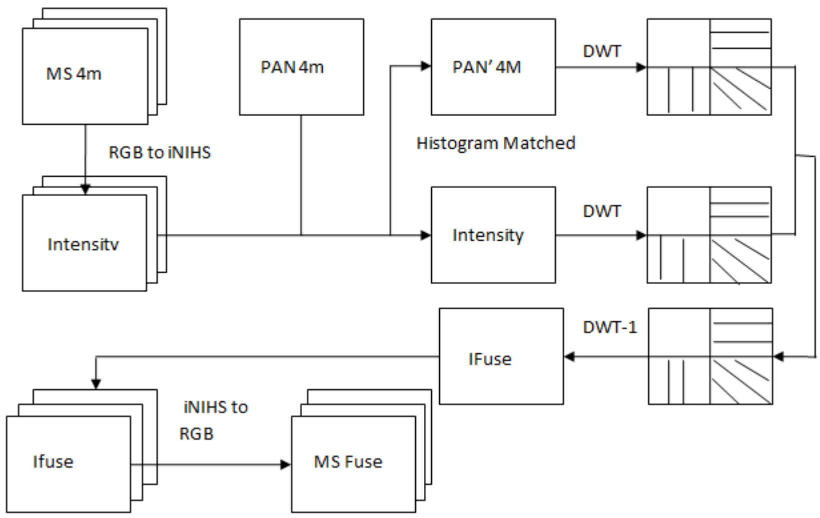


Fig. 5 Wavelet Based Additive Image Fusion

VI. References

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