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Survey on His Image Fusion Methods

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ABSTRACT :Due to inherent limitations on board in carrying the electronics and transferring the large volumes of data on to the ground, there is a requirement for finding out the methods for improving the spatial resolution by using image processing techniques. Data fusion in image processing addresses such requirements. When discussion is about data, it can be Optical, microwave or other sensors data. Data fusion can be further subdivided into multi-sensor fusion and image data fusion. The image fusion deals with the various techniques and algorithms used for combining image data. When satellite optical image data fusion is referred, it will narrow down the scope to fusion of optical image data acquired from satellites. The image fusion techniques referred to in this paper are developed for such data sets. Image fusion is the process to combine information from multiple images of the same area. The result of image fusion is a new image that retains the most desirable information and characteristics of each input image. The main application of image fusion is merging the gray-level high-resolution panchromatic [PAN] image and the colored low-resolution multispectral [MS] image.

KEYWORD : Image fusion, HIS, PAN, Multi spectral image, Spatial domain, Spectral domain

I. INTRODUCTION

Nowadays in remote sensing applications, the increasing availability of space sensors gives a motivation for different image fusion algorithms. Several situations in image processing require high spatial and spectral resolutions in a single image. But most of the available equipment is not capable of providing such information, either by design or because of observational constraints. The aim of the data fusion method is to combine two images that have been acquired at a different spatial resolution to produce an image with the spatial information of the high resolution image and the spectral information of the low spatial resolution image. There are mainly two types of data fusion process. They are multi sensor fusion and image data fusion. One of the component based method is the IHS. Thus image fusion techniques allow the integration of different information sources [2].

Image fusion can be used as a tool to increase the spatial resolution. In that case the high resolution panchromatic imagery is fused with low-resolution, often multi-spectral, image data. The multispectral images are images created from the several narrow spectral bands. It contains all spectral (colour information) details but not spatial details. Panchromatic images are single band images generally displayed as shades of gray [2]. It contains all high spatial details (geometric) but not spectral details. In satellite imaging, two types of images are available namely Panchromatic (PAN) images and Multi-Spectral (MS) images.PAN image is a single band image generally displayed as shades of gray. It is captured from the sensor which is sensitive to light of all wavelengths in the visible spectrum and thus it is a gray-scale image. The panchromatic image acquired by satellites is transmitted with the maximum resolution available. Thus PAN images contain the spatial details required for image fusion but totally are devoid of spectral details.MS image is an image created from several narrow spectral bands. It is formed using sensors that capture image data at specific frequencies across the electromagnetic spectrum, including light from frequencies beyond the visible light range, such as infrared. The wavelengths may be separated by filters.

II. NORMAL IHS TRANSFORMATION

The color monitors used for image display on image processing systems have three color guns. These correspond to red, green, and blue (R, G, B), the additive primary colors. When displaying three bands of a multiband data set, the viewed image is said to be in RGB space. However, it is possible to define an alternate color space that uses intensity (I), hue (H), and saturation (S) as the three positioned parameters (in line of R,G, and B) [5]. This system is advantageous in that it presents colors more nearly as perceived by the human eye. Intensity is the overall brightness of the scene and varies from 0 (black) to 1 (white). Saturation represents the purity of color and also varies linearly from 0 to 1. Hue is representative of the color or dominant wavelength of the pixel. It varies from 0 at the red midpoint through green and blue back to the red midpoint at 360. It is a circular dimension and must vary from 0 to 360 to define the entire sphere.

The standard merging methods of image fusion are based on Red-Green-Blue (RGB) to Intensity-Hue-Saturation (IHS) transformation. The usual steps involved in satellite image fusion are as follows:

1. Register the low resolution multispectral images to the same size as the panchromatic image.
2. Transform the R, G and B bands of the multispectral image into IHS components.
3. Modify the panchromatic image with respect to the multispectral image. This is usually performed by Histogram matching of the panchromatic image with Intensity component of the multispectral images as reference.
4. Replace the intensity component by the panchromatic image and perform inverse transformation to obtain a high resolution multispectral image.

III. RGB to HIS :

This enables to apply an algorithm which transforms red, green, and blue values to intensity, hue, and saturation (IHS) values [1].

The algorithm for RGB to IHS transformation:-

$R = (M-r) / (M-m)$ Eqn (1)

$G = (M-g) / (M-m)$ Eqn (2)

$B = (M-b) / (M-m)$ Eqn (3)

where:

R, G, B is each in the range of 0 to 1.0. r, g, b is each in the range of 0 to 1.0. M is largest value among r, g and b. m is least value among r, g, or b. At least one of the R, G, or B values is 0, corresponding to the color with the largest value, and at least one of the R, G, or B values is 1, corresponding to the color with the least value. The equation for calculating the intensity value in the range of 0 to 1.0 is:

$I= (M+m) / 2$ Eqn (4)

The equations for calculating saturation in the range of 0 to 1.0 are:

If $M = m$, $S = 0$

If $I <= 0.5$, $S = (M-m) / (M+m)$

If $I > 0.5$, $S = (M-m) / (2-M-m)$

The equations for calculating hue in the range of 0 to 360 are:

If $M = m$, $H = 0$

If $R = M$, $H = 60 * (2 + b - g)$

If $G = M$, $H = 60 * (4 + r - b)$

If $B = M$, $H = 60 * (6 + g - r)$

Where:

R, G, B is each in the range of 0 to 1.0.

M = largest value, R, G, or B

m = least value, R, G, or B

IHS to RGB :

This enables to transform intensity, hue, and saturation values to red, green, and blue values. The family of IHS to RGB is intended as a complement to the standard RGB to IHS transform. In the IHS to RGB algorithm, a min-max stretch is applied to either intensity (I), saturation (S), or both, so that they more fully utilize the 0 to 1 value range. The values for hue (H), a circular dimension, are 0 to 360. However, depending on the dynamic range of the DN values of the input image, it is possible that I or S or both occupy only a part of the 0 to 1 range. In this model, a min-max stretch is applied to I, S, or both, so that they more fully utilize the 0 to 1 value range. After stretching, the full IHS image is retransformed back to the original RGB space. As the parameter Hue is not modified, it largely defines what we perceive as color, and the resultant image looks very much like the input image. It is not essential that the input parameters (IHS) to this transform be derived from an RGB to IHS transform. We can define I and/or S as other parameters, set Hue at 0 to 360, and then transform to RGB space. This is a method of color coding other data sets. In another approach H and I are replaced by low- and high-frequency radar imagery. We can also replace I with radar intensity before the IHS to RGB transform. Chavez evaluates the use of the IHS to RGB transform to resolution merge Land sat TM with SPOT panchromatic imagery [5].

The algorithm for IHS to RGB function is:

Input: H in the range of 0 to 360; I and S in the range of 0 to 1.0

If $I <= 0.5$, $M = I * (1 + S)$

If $I > 0.5$, $M = I + S - I (S)$

$m = 2 * 1 – M$ Eqn (5)

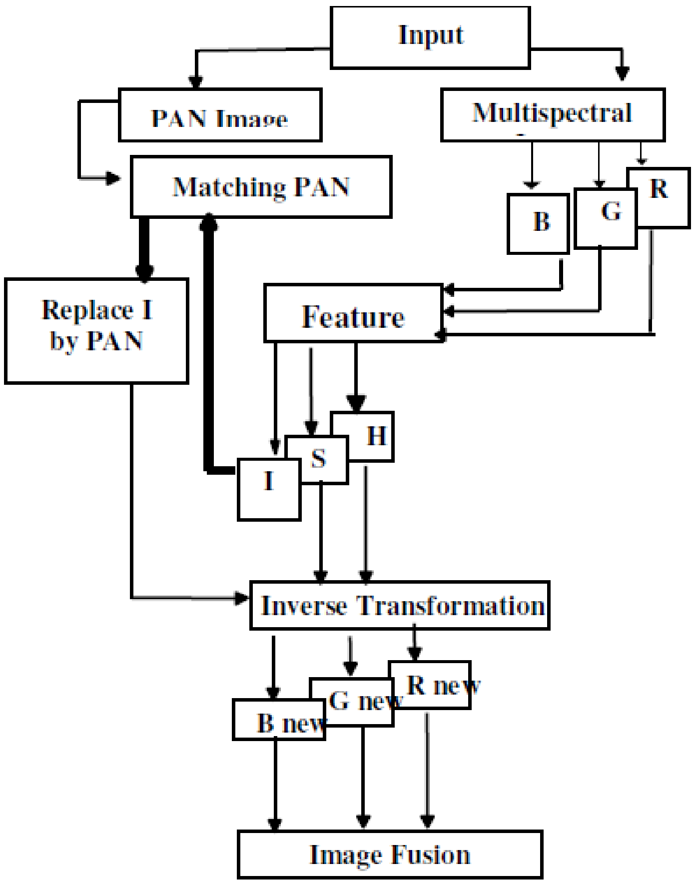
The equations for calculating R in the range of 0 to 1.0 are:

If $H < 60$, $R = m + (M - m)$

If 60 <=□H < 180, R = M
If 180 <=□H < 240, R = m + (M - m)
If 240 <=□H <=□360, R = m
The equations for calculating G in the range of 0 to 1.0 are:
If H < 120, G= m
If 120 <= H <180, G= m+ (M-m)*(H-120)/60
If 180 <= H < 300, G= M
If 300 <= H <= 360, G= m+ (M-m)*(360-H)/60
Equations for calculating B in the range of 0 to 1.0:
If H < 60, B= M
If 60 <= H <120, B= m+ (M-m)*(120-H)/60
If 120 <= H < 240, B= m
If 240 <= H < 300, B= m+ (M-m)*(H-240)/60
If 300<= H <= 360, B=M

IV. GENERAL IHS BASED IMAGE FUSION METHOD:

To reach image fusion goals, the IHS method uses three low-resolution multispectral images in distinct bands and transforms them into an IHS space [5].



HIS image fusion process

Let R0, G0, B0, V1o and V2o represent the corresponding values for the resized original image. In the IHS image fusion method, the intensity component of the IHS space is replaced by the high-resolution panchromatic image (PAN) and transformed back into the original RGB space with the previous H and S components.

$$\begin{bmatrix} R_{new} \\ G_{new} \\ B_{new} \end{bmatrix} = \begin{bmatrix} 1 & -1/\sqrt{2} & 1/\sqrt{2} \\ 1 & -1/\sqrt{2} & -1/\sqrt{2} \\ 1 & \sqrt{2} & 0 \end{bmatrix} \begin{bmatrix} Pan \\ \nu 1_0 \\ \nu 2_0 \end{bmatrix}. \qquad \text{Eqn (6)}$$

This is made computationally efficient by transforming like this:

$$\begin{bmatrix} R_{new} \\ G_{new} \\ B_{new} \end{bmatrix} = \begin{bmatrix} 1 & -1/\sqrt{2} & 1/\sqrt{2} \\ 1 & -1/\sqrt{2} & -1/\sqrt{2} \\ 1 & \sqrt{2} & 0 \end{bmatrix} \begin{bmatrix} I + (Pan\text{-}I) \\ \nu 1_0 \\ \nu 2_0 \end{bmatrix}$$

$$= \begin{bmatrix} 1 & -1/\sqrt{2} & 1/\sqrt{2} \\ 1 & -1/\sqrt{2} & -1/\sqrt{2} \\ 1 & \sqrt{2} & 0 \end{bmatrix} \begin{bmatrix} I + \delta \\ \nu 1_0 \\ \nu 2_0 \end{bmatrix}$$

$$= \begin{bmatrix} R_0 + \delta \\ G_0 + \delta \\ B_0 + \delta \end{bmatrix}$$

Eqn (7)

where $\boxed{\delta = Pan - I}$.

V. AN EFFICIENT SATURATION COMPENSATED HIS METHOD:

As explained by Te-Ming *et.al*, saturation compensation can be accomplished by simply shifting So to S' or by multiplying with $(1 + \Delta S/S_0)$. That is [7]:

$$\begin{bmatrix} R_s \\ G_s \\ B_s \end{bmatrix} = \begin{bmatrix} Pan \\ Pan \\ Pan \end{bmatrix} + \left(1 + \frac{\Delta S}{S_0}\right) \begin{bmatrix} -1/\sqrt{2} & 1/\sqrt{2} \\ -1/\sqrt{2} & -1/\sqrt{2} \\ \sqrt{2} & 0 \end{bmatrix} \begin{bmatrix} \nu 1_0 \\ \nu 2_0 \end{bmatrix},$$

Eqn (8)

It is made computationally efficient by:

$$\begin{bmatrix} R_s \\ G_s \\ B_s \end{bmatrix} = \begin{bmatrix} 1 & -1/\sqrt{2} & 1/\sqrt{2} \\ 1 & -1/\sqrt{2} & -1/\sqrt{2} \\ 1 & \sqrt{2} & 0 \end{bmatrix} \begin{bmatrix} Pan \\ \gamma' \cdot \nu 1_0 \\ \gamma' \cdot \nu 2_0 \end{bmatrix}$$

$$= \begin{bmatrix} 1 & -1/\sqrt{2} & 1/\sqrt{2} \\ 1 & -1/\sqrt{2} & -1/\sqrt{2} \\ 1 & \sqrt{2} & 0 \end{bmatrix} \begin{bmatrix} \gamma' \cdot I + (Pan - \gamma' \cdot I) \\ \gamma' \cdot \nu 1_0 \\ \gamma' \cdot \nu 2_0 \end{bmatrix}$$

$$= \gamma' \cdot \begin{bmatrix} R \\ G \\ B \end{bmatrix} + \begin{bmatrix} \gamma'' \\ \gamma'' \\ \gamma'' \end{bmatrix},$$

Eqn (9)

where $\gamma' = I/Pan = 1 + \Delta S/S_0$ and $\gamma'' = Pan - \gamma' \cdot I,$.

VI. INTENSITY MATCHED HIS

This is also same as normal HIS method. Let R0, G0, B0, V1o and V2o represent the corresponding values for the resized original image. In the IHS image fusion method, the intensity component of the IHS space is replaced by the high-resolution panchromatic image (PAN) and transformed back into the original RGB space with the previous H and S components. But only difference is here the intensity component of the HIS is not directly replaced. The histogram quantization of the intensity image is replaced with the high resolution panchromatic image and then transformed back into the original RGB space with same as the above method [6].

VII. EXPERIMENTAL RESULTS

The following data presents thumbnails of the output images and also compares them using the parameters like mean, median, standard deviation and universal image quality index (Q-factor).The methods are implemented on normal images.

Multispectral image

Panchromatic image

Normal HIS

Saturated compensated HIS

Intensity matched HIS

General IHS

From the above data, it can be found out that SATURATED COMPENSATED HIS method outperforms the NORMAL IHS method. The HIS method performs better than YIQ, and in particular, because the spectral distortion in the fused bands is usually less noticeable, even if it cannot be completely avoided. The wavelet based method can further reduce the spectral distortion, and thus the SATURATED COMPENSATED HIS fusion method is the best choice in most cases. Thus spatial domain fusions like IHS, HSV and YIQ may produce spectral degradation. This is particularly crucial in optical remote sensing if the images to fuse were not acquired at the same time. Therefore, compared with the ideal output of the fusion, these methods often produce poor result.

IMAGE QUALITY ASSESSMENT

Table :1 **Universal Quality index**

METHOD	Q-factor
Normal HIS method	0.401
Intensity matched HIS	0.390
Saturated compensated HIS	0.590
General HIS	0.491

Table : 2 **Image Quality Analysis**

TECHNIQUES	SSIM VALUES		
	BAND 1	BAND 2	BAND 3
Normal IHS	0.0240	0.1136	-0.0216
Generalized IHS	0.0240	0.1136	-0.0216
Intensity matched IHS	0.0179	0.1144	0.0251
Saturation compensation IHS	0.0239	0.1116	-0.0219

Universal Image Quality Index [Q-factor] :
Universal Image quality index is a new type of quality index proven to be better than widely used distortion metric mean squared error. Instead of using traditional error summation methods, this index is designed by modeling the image distortion as a combination of three factors: loss of correlation, luminance distortion, and contrast distortion [8] . Its definition is given below:-

Let $\mathbf{x} = \{x_i | i = 1, 2, \cdots, N\}$ and $\mathbf{y} = \{y_i | i = 1, 2, \cdots, N\}$ be the original and the test image signals, respectively. quality index is defined as

$$Q = \frac{4\,\sigma_{xy}\,\bar{x}\,\bar{y}}{(\sigma_x^2 + \sigma_y^2)\,[(\bar{x})^2 + (\bar{y})^2]} \ ,$$

where

$$\bar{x} = \frac{1}{N}\sum_{i=1}^{N} x_i \ , \qquad \bar{y} = \frac{1}{N}\sum_{i=1}^{N} y_i \ ,$$

$$\sigma_x^2 = \frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})^2 \ , \quad \sigma_y^2 = \frac{1}{N-1}\sum_{i=1}^{N}(y_i - \bar{y})^2 \ ,$$

$$\sigma_{xy} = \frac{1}{N-1}\sum_{i=1}^{N}(x_i - \bar{x})(y_i - \bar{y}) \ .$$

Eqn (10)

The dynamic range of Q is [-1, 1]. The best value 1 is obtained only if X=Y and the lowest value -1 occurs when $y_i = 2\bar{x} - x_i$ for all i=0, 1, 2… N.

SSIM

Structural Similarity is based on the idea that the human visual system is highly adapted to process structural information and the algorithm attempts to measure the change in this information between and reference and distorted image. Based on numerous tests, SSIM does a much better job at quantifying subjective image quality than MSE or PSNR [3].

At a high level, SSIM attempts to measure the change in luminance, contrast, and structure in an image. Luminance is modeled as average pixel intensity, contrast by the variance between the reference and distorted image, and structure by the cross-correlation between the 2 images. The resulting values are combined (using exponents referred to as alpha, beta, and gamma) and averaged to generate a final SSIM index value.

VIII. CONCLUSION & FUTURE SCOPE

In this thesis, the various optical data image fusion methods are studied. The implementation methods of all the mentioned fusion methods have been presented which are implemented. The fusion methods implemented are Normal Intensity-Hue-Saturation (IHS) fusion, General HIS, Intensity matched HIS, Saturated compensated HIS. The output results of the each method are presented.

It can be concluded from experimental results that the selection of a particular fusion methods depends on the application at hand. In case of fusing for urban areas spatial resolution is of importance and for agricultural fields spectral is more important than spatial. Hence a method which can preserve both of these equally is desirable. From the implemented methods Modified HIS and Saturated compensated HIS methods are good at preserving spatial quality, Where as Normal HIS and General HIS methods are good at preserving the spectral quality. From the statistics it is observed that for the given sample images, saturation compensated IHS scheme outperforms the Normal HIS scheme while Saturated compensated HIS scheme has the best performance with respect to spatial preservation. The algorithms are implemented using Open CV code. These can be ported in to standalone modules by using open source software libraries like Geo spatial Data abstraction library (GDAL), OSSIM etc…

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