EFFICIENT IHS BASED IMAGE FUSION WITH "COMPENSATIVE" MATRIX CONSTRUCTED BY SIMULATING THE SCALING PROCESS

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ABSTRACT:

The intensity-hue-saturation (IHS) technique has become a standard procedure in image analysis. It enhances the colour of highly correlated data. Unfortunately, IHS technique is sensitive to the properties of the analyzed area and usually faces colour distortion problems in the fused process. This paper explores the relationship of colour between before and after the fused process and the change in colour space of images. Subsequently, the fused colours are transformed back into the "simulative" true colours by the following steps: (1) For each pixel of fused image that match with original pixel (of the coarse spectral resolution image) is transformed back to the true colour of original pixel. (2) The value for interpolating pixels is compensated to preserve the DN ratio between the original pixel and it's vicinity. The "compensative matrix" is constructed by the DN of fused images and simulation of scaling process. An illustrative example of a Landsat and SPOT fused image also demonstrates the simulative true colour fusion methods.

KEY WORDS: intensity, hue, saturation (IHS), image fusion, compensation

1. INTRODUCTION

The more developed the economy, the more countries can launch the scientific satellite to the space. Consequently, the more new imaging styles have used to serve the global observation, management and so on. Thus a combinational method is needed for all employed imaging sources. An image fusion is quite a novel means for combining the spectral information of coarse resolution image with the spatial resolution of a finer image. Fused images may provide increased interpretation capabilities and more reliable results since data with different characteristics are combined. Image fusion is for integrating different data in order to obtain more information than that the derived from each of the single sensor data alone "1 + 1 = 3" (Pohl C., 1998). Recently, there have been many fusion methods in the remote sensing community (Chavez *et al.*, 1991). The IHS is the one of the most widely used image fusion methods (Kathleen *et al.*, 1994, Chavez *et al.*, 1991). To make the fusing image, the IHS colour transformation effectively separates spatial (I) and spectral (H, S) information from a standard RGB of coarse resolution image. Subsequently, the intensity component of IHS space is replaced by the finer resolution of another image and transformed back into the original RGB form with previous H and S components (Caper *et al.*, 1990; Gonzales and Woods, 1992; Pohl C., 1998; Harrison and Jupp, 1990). The IHS fusion image proves the capability for exploration, detection, and object recognition and so on. But it is sensitive to characteristics of the analyzed area because it usually experience difficulties such as the colour distortion in the fusing process (Ledley *et al.*, 1990). To overcome the colour distortion of fused image, we have investigated the change in the colour in the transformation (RGB to IHS) and transformation-back (HIS to RGB) process, and the relationship among RGB values of image before and after fusing process. Finally, we present a method to transform the colour of the fused image back into the original colour. Meanwhile, the spectral balance bands of the fused image are preserved. Hopefully, it will become a good supplement for traditional methods such as "Histogram matching" or Fourier algorithm and so on. An illustrative example of fusion among Landsat and SPOT-XP image demonstrates for each stage of the paper.

2. METHOD

2.1 Fusing image

There are some mathematical representations of transformation that can convert threesome RGB values into parameters of human colour perception and vice versa. Here, we used a widespread mathematical formula of Harrison and Jupp that presented since 1990. The mathematical context is expressed by equations (1), (2). Variables v_1 and v_2 in the equations (1), (2) can be considered as x and y in the Cartesian coordinates system, while intensity (I) indicates the z axis. Hence, the hue (H) and saturation (S) can be expressed by equations (3), (4).

$$\begin{pmatrix} I \\ v_1 \\ v_2 \end{pmatrix} = \begin{pmatrix} \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{3}} \\ \frac{1}{\sqrt{6}} & \frac{1}{\sqrt{6}} & -\frac{2}{\sqrt{6}} \\ \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{2}} & 0 \end{pmatrix} * \begin{pmatrix} R_O \\ G_O \\ B_O \end{pmatrix} \quad (1)$$

$$\begin{pmatrix} R_o \\ G_o \\ B_o \end{pmatrix} = \begin{pmatrix} \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{6}} & \frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{6}} & -\frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{3}} & -\frac{2}{\sqrt{6}} & 0 \end{pmatrix} * \begin{pmatrix} I \\ v_1 \\ v_2 \end{pmatrix} \tag{2}$$

$$H = \tan^{-1}\left(\frac{v_2}{v_1}\right) \quad (3); \qquad S = \sqrt{v_1^2 + v_2^2} \quad (4)$$

The illustrative example of the paper uses 3 bands (1; 2; 3) of Landsat TM and a panchromatic band (XP) of SPOT for fusing image. After scaling and re-sampling preprocess, we use the IHS method to transform threesome Landsat multi-spectral bands into an IHS space following equation (1). To reach image fusion goals, we replaced the I value of the IHS space by the finer resolution panchromatic (XP) of SPOT image and transformed IHS space back into RGB space with previous v_1 and v_2 values following equation (5).

$$\begin{pmatrix} R_f \\ G_f \\ B_f \end{pmatrix} = \begin{pmatrix} \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{6}} & \frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{6}} & -\frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{3}} & -\frac{2}{\sqrt{6}} & 0 \end{pmatrix} * \begin{pmatrix} XP \\ v_1 \\ v_2 \end{pmatrix} \tag{5}$$

Figure 1. The Landsat TM image after scaling, re-sampling preprocess (left) and the fused image (right)

At first sight, the colour of fused image looks similar with the original image. However, the distinction between the two images will appear immediately after a simply processing.

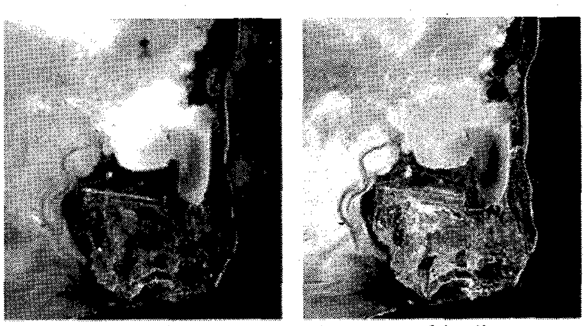


Figure 2: Two images after "Auto stretching" process.

And the colour distortion is shown evidently when we carry out the histogram scheme for two image.

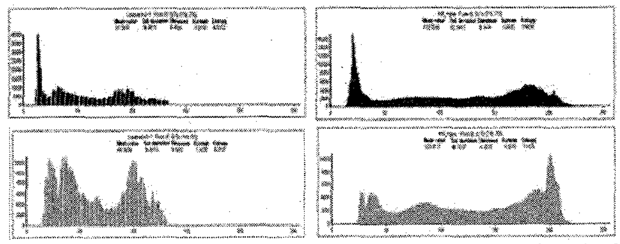


Figure 3. The histogram scheme of red and green band of original image (left) and fused image (right).

2.2 Transformation back to the original RGB with colour "compensate" matrix for fused image

To reach the original colour goals, we investigated the change in the colour components in transformation back process. First, multiplying and dividing the "Harrison and Jupp" transformative matrix on the right-hand side of the equation (5) by $\frac{1}{\sqrt{3}}$.

$$\begin{pmatrix} R_f \\ G_f \\ B_f \end{pmatrix} = \frac{1}{\sqrt{3}} \begin{pmatrix} 1 & \frac{1}{\sqrt{2}} & \frac{\sqrt{3}}{\sqrt{2}} \\ 1 & \frac{1}{\sqrt{2}} & -\frac{\sqrt{3}}{\sqrt{2}} \\ 1 & -\sqrt{2} & 0 \end{pmatrix} * \begin{pmatrix} XP \\ v_1 \\ v_2 \end{pmatrix} \tag{6}$$

Replace the XP by (I + XP - I), the equation (6) can be rewritten as the equations (7) and (8).

$$\begin{pmatrix} R_f \\ G_f \\ B_f \end{pmatrix} = \frac{1}{\sqrt{3}} \begin{pmatrix} 1 & \frac{1}{\sqrt{2}} & \frac{\sqrt{3}}{\sqrt{2}} \\ 1 & \frac{1}{\sqrt{2}} & -\frac{\sqrt{3}}{\sqrt{2}} \\ 1 & -\sqrt{2} & 0 \end{pmatrix} * \begin{pmatrix} I+\Delta \\ v_1 \\ v_2 \end{pmatrix} \tag{7}$$

$$\begin{pmatrix} R_f \\ G_f \\ B_f \end{pmatrix} = \left\{ \begin{pmatrix} \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{6}} & \frac{1}{\sqrt{2}} \\ \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{6}} & -\frac{2}{\sqrt{2}} \\ \frac{1}{\sqrt{3}} & -\frac{2}{\sqrt{6}} & 0 \end{pmatrix} * \begin{pmatrix} I \\ v_1 \\ v_2 \end{pmatrix} + \begin{pmatrix} \frac{\Delta}{\sqrt{3}} \\ \frac{\Delta}{\sqrt{3}} \\ \frac{\Delta}{\sqrt{3}} \end{pmatrix} \right\} \tag{8}$$

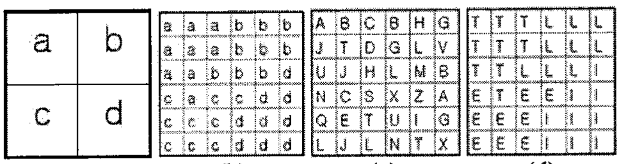
Let v_1, v_2 and I represent the corresponding values for transforming the original image to IHS space. They can be easily determined from equation (1). Note that the R_o, G_o, B_o values in equation (2) and equation (8) can be expressed as:

$$\begin{pmatrix} R_f \\ G_f \\ B_f \end{pmatrix} = \begin{pmatrix} R_o \\ G_o \\ B_o \end{pmatrix} + \begin{pmatrix} \frac{\Delta}{\sqrt{3}} \\ \frac{\Delta}{\sqrt{3}} \\ \frac{\Delta}{\sqrt{3}} \end{pmatrix} = \begin{pmatrix} R_o + \frac{\Delta}{\sqrt{3}} \\ G_o + \frac{\Delta}{\sqrt{3}} \\ B_o + \frac{\Delta}{\sqrt{3}} \end{pmatrix} \tag{9}$$

$$\begin{pmatrix} R_o \\ G_o \\ B_o \end{pmatrix} = \begin{pmatrix} R_f - \frac{\Delta}{\sqrt{3}} \\ G_f - \frac{\Delta}{\sqrt{3}} \\ B_f - \frac{\Delta}{\sqrt{3}} \end{pmatrix} \tag{10}$$

Equation (9) points out that the fused image $[R_f G_f B_f]^T$ can be easily obtained from the original image $[R_o G_o B_o]^T$.

Equation (10) states that the colour of fused image can be transformed back into original colour by some operations. However, equation (10) may be right for the pixels of the initial image (It is Landsat image before scaling process in this paper). These pixels play the leading role in the scaling process. They are called "original pixels" in the paper. The other pixels result from "original pixels" by scaling process and they are named "interpolating pixels". The colour of interpolating pixels may be changed after fusion by effect of saturation (Tu *et al.*, 2005). To overcome this problem, we present the "compensative matrix".

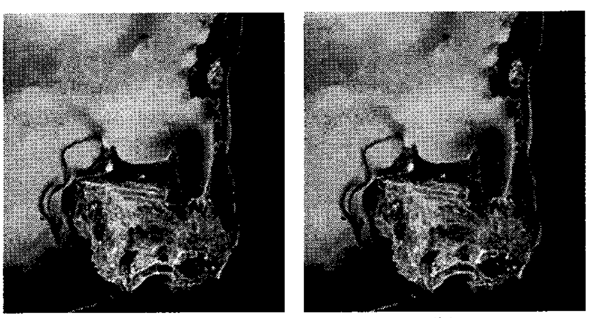


(a) (b) (c) (d)

Figure 4. (a) Four pixels of Landsat image (1 pixel = $30*30m^2$) (b) Landsat image after scaling process (1 pixel = $10*10m^2$) (c) Fusion image (Example, red band) (d) Compensative matrix (for red band)

The objectives of "compensative matrix" are as follows:

- For each pixel of fused image that matching with the original pixel is transformed back into true colour of original pixel.
- Compensating value for interpolating pixels so as to preserve the DN ratio between original pixel and its vicinity.



(a) (b)

Figure 5. The red band of fused image (b) the "compensative matrix" for the red band of fused image

The "compensative matrix" is constructed by simulation of the scaling process following step:

① Scaling the coarse spectral image (Figure 4 (a)) to finer spectral image (Figure 4 (b)). The red shows the pixels that not change value during the scaling process. They are called original points. In this paper, we use the "Nearest Neighbor" simple method to scale image.

② Effort is made to find the matching point in the fused image for each original point. The red pixels (Figure 4 (c)) show the matching points in fused image for original points.

③ The "compensative matrix" is constructed by iterating the scaling process for new values of fused image that to have just found in the "matching point" process. Figure 4 (d) shows the "compensative matrix" of the illustrative sample.

To achieve the above objective, we carefully considered the following equations:

$$DN_{new} = \frac{DN_{fusion}}{DN_{compensation}} * DN_{origin} \tag{11}$$

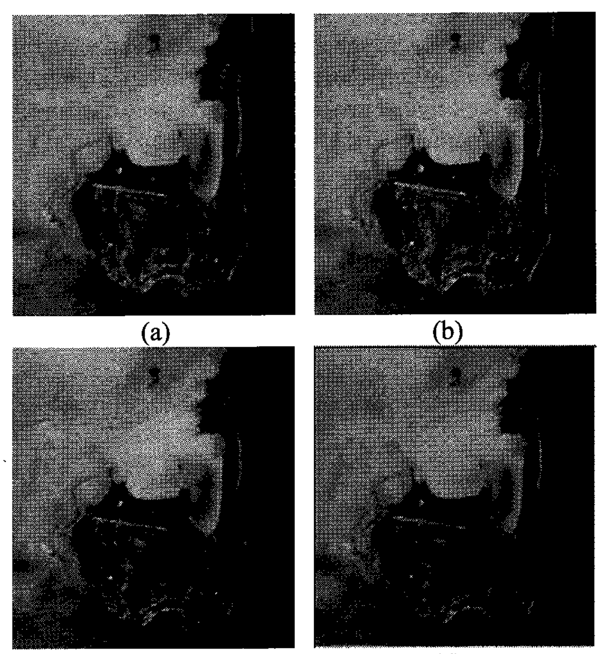
$$DN_{new} = \frac{DN_{compentition}}{DN_{fusion}} * DN_{origin} \tag{12}$$

$$DN_{new} = \frac{1}{2} * \left[\frac{DN_{fusion}}{DN_{compensation}} + \frac{DN_{compensation}}{DN_{fusion}} \right] * DN_{origin} \tag{13}$$

- For each of the original (matching) point, DNfusion = $DN_{compensation}$ then $DN_{new} = DN_{origin}$. So the colour of fused image transformed back into colour of original image.
- For other points of original image, the pixels values can be computed by equations above. Note that the DN ratio of the surrounding original point did not change in transformed back process.

With regard to matching point T and it's vicinity in figure 4 (d). Clearly, the A/B/C/J/D/U/J is quite equal $\frac{A*a}{T} / \frac{B*a}{T} / \frac{C*a}{T} / \frac{J*a}{T} / \frac{D*a}{T} / \frac{U*a}{T} / \frac{J*a}{T}$ ratio of the respective pixels in the transform back image that resulted from equation (13).

3. RESULT



(a) (b)

(c) (d)

Figure 6. (a), (b), (c) The fused image transformed back into RGB space by equation (13), (11), (12) (d) Original image

As you can see, compared with the original image (6 (d)), the colour of transformation back image is very close to (6 (a), (b), (c)). Furthermore, the colour of both images is also very similar with in some image processing.

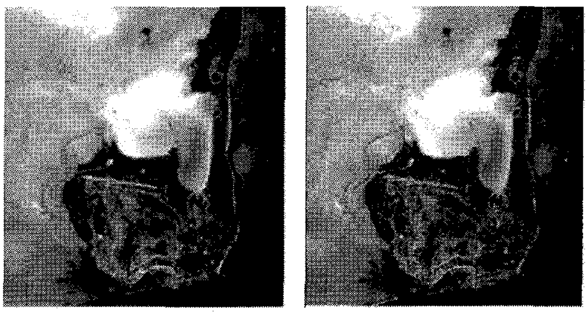


Figure 7. The comparison between original and transformation-back image 7 (b) by "Auto-linear stretching" process

To accurately estimate the similar colours between the two images, we compared the shape of histogram schemes (Figure 8)and histogram parameters of those images.

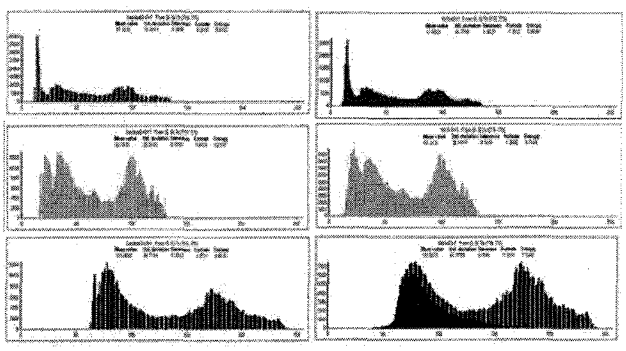


Figure 8. Histogram schemes (Note: Rows indicate the histograms of red, green and blue bands. Columns indicate the original image (left) and transformed-back image (right) of Figure 6. (b).)

Table 1. Comparing histogram parameters for RGB band

Red	**Mean**	**StdDev**	**Skewness**	**Kustosis**	**Entropy**
Org*	57.3698	35.6911	0.3006	-1.2150	6.2312
Fusion*	113.7560	65.2443	-0.1440	-1.4175	7.4636
Ncf*	57.6528	35.7798	0.3029	-1.1852	6.6860
Nfc*	57.7494	36.6130	0.3310	-1.0473	6.7489
N*	57.6599	35.6928	0.2925	-1.2028	6.3713
Green					
Org	66.14380	33.5415	0.1663	-1.4120	6.2727
Fusion	130.0113	60.7237	-0.2830	-1.3570	7.4126
Ncf	66.5151	33.6265	0.1489	-1.3994	6.7273
Nfc	66.3135	34.1517	0.1505	-1.3692	6.7443
N	66.3725	33.4620	0.1517	-1.4044	6.4019
Blue					
Org	133.3083	50.7349	0.2262	-1.3751	6.8032
Fusion	216.8151	52.3957	-1.0110	-0.5168	4.2170
Ncf	133.6741	50.8189	0.1918	-1.3523	7.1287
Nfc	133.4075	51.1708	0.1846	-1.3595	7.1388
N	133.5178	50.5818	0.2249	-1.3705	6.9185

- Org*: Original image (Landsat image after the scaling process)
- Fusion*: Fused image
- Ncf*, Nfc*, N*: The fused image transformed back into original colour by equation (13), (12), (11); (Figure 6. (c), (b), (a) respectively.

4. CONCLUSION

This paper presents a simple transformation back process with the compensative matrix. The original pixels is restored back to their own colour after image fusion. The DN ratio between original point and vicinity is also preserved. The relationship of histogram schemes between original image and transformation-back image is very similar. An example using Landsat and SPOT data showed similar conclusions. However, in the case of $DN_{compensation}$ or DN_{fusion} value equals zero, the DN value of transformed-back image was imposed. Hopefully, "compensative" matrix is able to become a good supplement for traditional methods such as "Histogram matching" or Fourier algorithm and so on.

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