



Improving Spatial Resolution Of Satellite Image Using Data Fusion Method

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Abstract

While many remote sensing and GIS applications require both the spatial resolution and spectral resolution be high, image fusion, or in other words, image sharpening, is a useful technique. To date, numerous image fusion techniques have been developed to combine the clear geometric features of the panchromatic image and the color information of the multispectral image. This paper compares the results of four different pixel based fusion techniques, HLS, Brovey transformation, Gram-Schmidt and HSV techniques used to merge the ETM+ multispectral image with (28.5 m) spatial resolution and panchromatic image captured by SPOT satellite with (10m) spatial resolution, correlation coefficient, root mean square error and peak signal to noise ratio criteria have been used to achieve the comparison among the using techniques.

Keyword: image fusion, HLS, Brovey, Gram-Schmidt.

تحسين الدقة الحيزية للصور الفضائية باستخدام طرق الاندماج

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الخلاصة

ان تطبيق تقانات الاستشعار عن بعد ونظم المعلومات الجغرافية تحتاج الى صور ذات دقة حيزية وطيفية عالية، لذلك ظهرت تقانات اتحاد الصور كضرورة لتحسين الصور ذات الدقة الحيزية الواطئة بواسطة دمجها مع صور ذات دقة حيزية عالية، في هذا البحث تم استخدام اربع طرق لدمج الصور تتمثل هذه الطرق ب HLS, HSV, Brovey, Gram-Schmidt لغرض دمج صور متعددة الاطراف ملتقطة بالمتحسس (ETM+) ذات الدقة الحيزية (28.5m) مع صورة احادية بدقة حيزية (10m). تم استخدام عدة معايير مثل (PSNR , RMSE,CC) لاغراض المقارنة بين الطرق المستخدمة.

1. Introduction

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. In remote sensing applications; the increasing availability of space borne sensors gives a

motivation for different image fusion algorithms. Several situations in image processing require high spatial and high spectral resolution in a single image. Most of the available equipments is not capable of providing such data convincingly. The image fusion techniques allow the integration of different

information sources. The fused image can have complementary spatial and spectral resolution characteristics. However, the standard image fusion techniques can distort the spectral information of the multispectral data while merging.

Satellites provide two types of image data: panchromatic imagery with high-spatial (but low spectral) resolution and multispectral images with lower spatial (but higher spectral) resolution. Image fusion techniques, as an alternative solution can be used to integrate the geometric detail of a high-resolution Pan image and the color information of low-resolution MS images to produce a high-resolution MS image, [1,2]. The primary objective of this paper is to apply four different fusion techniques on enhance thematic mapper (ETM+) multispectral

with three band (red, green, blue) and panchromatic image exposure by SPOT satellite. The technique that have been used in this paper include (HLS, Brovey, Gram-Schmidt and HSV).

The comparison between the result fused image three objective fidelity criteria RMSE (root mean square error), PSNR (peak signal to noise ratio), and CC (correlation coefficients).

2. Methodology

Four fusion techniques have been adopted to get high resolution image combine from the panchromatic and multispectral image of mousel city lies in the north of Iraq, the image of the studied area and its statistical properties can be shown in the figure (1) and table (1) respectively. The details of the adopted four methods can be shown in the next section:

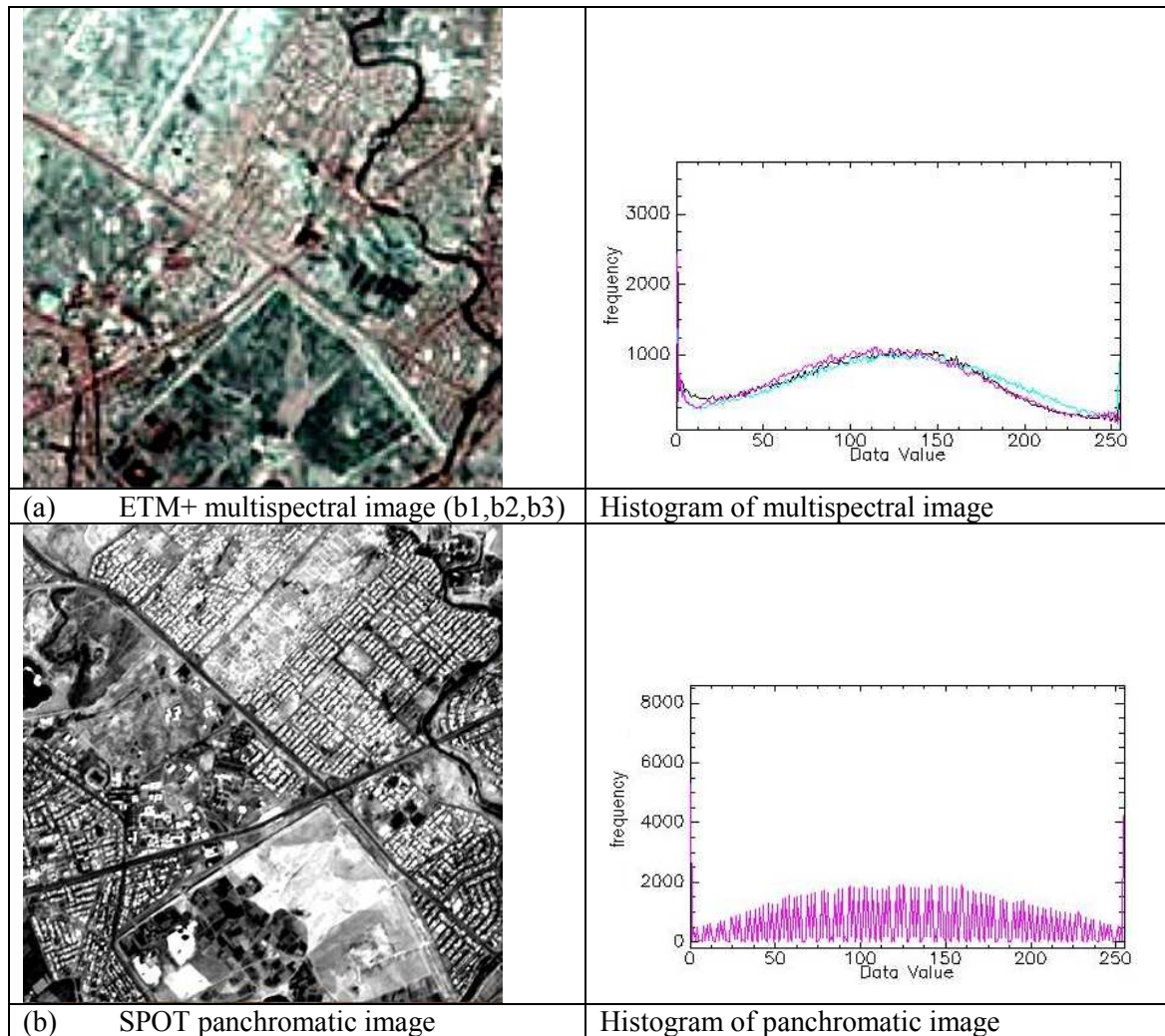


Figure 1- A. Original Image With Spatial Resolution(28.5m) Consist Of Three Bands Captured By ETM+. B. Panchromatic Image With High Resolution (10 M) .Captured By SPOT.

Table 1- Statistic Properties Of The Original Images.

image	No.of bands	Min.	Max.	Mean	Stdev.
Multispectral(ETM+)	Band1	0	255	113.97763	58.86576
	Band2	0	255	124.42161	60.18855
	Band3	0	255	115.11013	56.87623
Panacromatic(SPOT)	Band1	0	255	129.134861	69.713729

2.1 Hls (Hue Light Saturation)

Transform.

The HIS transform is always applied to an RGB composite. This implies that the fusion will be applied to groups of three bands of the MS image. As a result of this transformation, we obtain the new intensity, hue, and saturation components. The PAN image then replaces the intensity image. Before doing this, and in order to Minimize the modification of the spectral information of the fused MS image with respect to the original MS image, the histogram of the PAN image is matched with that of the intensity

image. Applying the inverse transform, we obtain the fused RGB image, with the spatial detail of the PAN image incorporated into it. The geometry of HLS (Hue light saturation) can be shown in figure (2), with hue, their angular dimension, starting at the red primary at 0°, passing through the green primary at 120° and the blue primary at 240°, and then wrapping back to red at 360°. In each geometry, the central vertical axis comprises the neutral, achromatic, or gray colors, ranging from black at lightness 0 or value 0, the bottom, to white at lightness 1 or value 1.

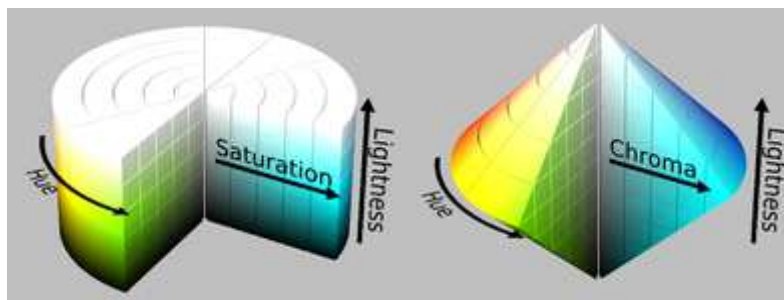


Figure 2- a. HLS Cylinder, b. HLS Lightness

Many mathematical models of transformation to convert RGB into the parameters of human color perception and vice versa, [3,4]. These transformations differ mainly depended on the coordinates system (cylindrical or spherical coordinates), the primary color use as the hue references point, and the method used to calculate the intensity component of the transformation. To understand the color distortion during the image fusion process, there are two type of conversion linear transformation which can be define as:

$$\begin{bmatrix} I \\ v1 \\ v2 \end{bmatrix} = \begin{bmatrix} 1/3 & 1/3 & 1/3 \\ -\sqrt{2}/6 & -\sqrt{2}/6 & 2\sqrt{2}/6 \\ 1/\sqrt{2} & -1/\sqrt{2} & 0 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \dots\dots\dots(1)$$

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1 & -1/\sqrt{2} & 1/\sqrt{2} \\ 1 & -1/\sqrt{2} & -1/\sqrt{2} \\ 1 & \sqrt{2} & 0 \end{bmatrix} \begin{bmatrix} I \\ v1 \\ v2 \end{bmatrix} \dots\dots\dots (2)$$

Where

v1, v2, I : represent x, y, z in Cartesian coordinates system respectively.

So hue (H) and saturation(S) can be defined as:

$$H = \tan^{-1} \left(\frac{v2}{v1} \right) \dots\dots\dots(3)$$

$$S = \sqrt{v1^2 + v2^2} \dots\dots\dots(4)$$

RGB cube can be rotated until the horizontal plane is parallel to the Maxwell triangle and the vertical axis lies on the gray line of the RGB cube. As such, a nonlinear RGB-HIS conversion system can be represented:

$$I = (R + G + B) / 3$$

$$H = \begin{cases} \cos^{-1}(a) & \text{if } G \geq R \\ 2\pi - \cos^{-1}(a) & \text{if } G < R \end{cases} \quad (5)$$

$$a = \frac{(2B - G - R) / 3}{\sqrt{(B - G)^2 + (B - R)(G - R)}} \quad (6)$$

$$S = 1 - \frac{3 \min(R, G, B)}{R + G + B} \quad (7)$$

2.2 HSV (Hue Saturation Value) Transformation.

a) RGB to HSV: Transforms an RGB image into the HSV color space. The input RGB values must be byte data in the range 0 to 255. You must have either an input file with at least three bands or a color display open to use this function. The stretch that is applied in the color display is applied to the input data. The hues produced are in the range of 0 to 360 degrees (where red is 0 degrees, green is 120 degrees, and blue is 240 degrees) and saturation and value in the range 0 to 1 (floating-point).

b) HSV to RGB: Transforms an HSV image back to the RGB color space. The input H, S, and V bands must have the following data ranges: Hue = 0 to 360, where 0 and 360 = blue, 120 = green, and 240 = red; Saturation ranges from 0 to 1.0 with higher numbers representing more pure colors; Value ranges from approximately 0 to 1.0 with higher numbers representing brighter colors. The RGB values produced are byte data in the range 0 to 255.[5]

2.3. Fusion Image Based On The Gram-Schmidt Process.

The Gram Schmidt fusion simulates a panchromatic band from the lower spatial resolution spectral bands. In general, this is achieved by averaging the multispectral bands. As the next step, a Gram Schmidt transformation is performed for the simulated panchromatic band and the multispectral bands with the emulated panchromatic band employed as the first band. Then the high spatial resolution panchromatic band replaces the first Gram Schmidt band. Finally, an inverse Gram Schmidt transform is applied to create the pan sharpened multispectral bands [6,7]. This method usually produces good results for fusion images from one sensor as well as different sensors.

2.4. Fusion image based on Brovey transform.

The Brovey transform is based on the mathematical combination of the multispectral images and high resolution Pan image. Each multispectral image is normalized based on the other spectral bands and multiplied by the Pan image to add the spatial information to the output image. The following equation shows the mathematical algorithm for the Brovey method [8].

$$F_i = \frac{M_i}{\sum_{j=1}^N M_j + c} \times P \quad (8)$$

Fi: fused image
 Mi: multispectral band to be fused
 P: panachromatic band
 $\sum_{j=1}^N M_j$: sum of all multispectral bands

In some cases there is an area with zero DN values for all bands; therefore a constant C has to be added in the denominator to produce meaningful output digital numbers.

3. Statistical Comparison

In this study evaluation method was employed to assess the synthesis property of fused images. The fused images are re-sampled to the resolution of the original multispectral images, the statistical criteria include:

Correlation Coefficient (CC): The correlation coefficient measures the closeness or similarity in small size structures between the original and the fused images. It can vary between -1 and +1. Values close to +1 indicate that they are highly similar while the values close to -1 indicate that they are highly dissimilar, [9].

$$cc = \frac{\sum_{i=1}^N \sum_{j=1}^N (MS_{i,j} - \overline{MS})(F_{i,j} - \overline{F})}{\sqrt{\sum_{i=1}^N \sum_{j=1}^N (MS_{i,j} - \overline{MS})^2 \sum_{i=1}^N \sum_{j=1}^n (F_{i,j} - \overline{F})^2}} \quad (9)$$

Where
 CC is the Correlation Coefficient,
 F is the fused image and i and j are pixels,
 MS is the original data.

RMSE (Root Mean Square Error): consider to be good criteria to achieve the evaluation

between the original and process images. It can be given as:

$$PSNR = 10 \log_{10} \frac{(L-1)^2}{\frac{1}{NM} \sum_{i=1}^N \sum_{j=1}^M (MS_{i,j} - F_{i,j})^2} \quad (10)$$

PSNR (peak signal to nose ratio): is another objective fidelity criteria has been used to perform the comparison between the original and fused image, and it can be defined as follow:

$$RMSE = \sqrt{\frac{1}{NM} \sum_{i=1}^N \sum_{j=1}^M (MS_{i,j} - F_{i,j})^2} \dots (11)$$

Where:

N,M=size of the image.

MS=original image.

F=fused image.

L=no.of the image gray levels, for 8bit, L=256.

4. Result and Conclusions

The fusing techniques have been used to enhance the spatial resolution of multispectral image captured by ETM+ (28.5m) by combining it with high resolution panchromatic image exposure by SPOT with spatial resolution (10m). the original image with its statistical properties can be shown in figure(1) and table

(1) respectively. The result of fused image using HLS and brovey can be shown in figure (3), while fused images using Gram–Schmidt and HSV can be shown in figure (4).

The Statistical comparison between the original and fused image have been achieved using many objective criteria such as RMSE (root mean square error), PSNR (peak signal to nose ratio), and CC (correlation coefficient), where the result of the criteria prove that Gram–Schmidt fusing technique have more correlation coefficient than the other techniques, as well as Gram–Schmidt have good value of PSNR comparison with the other techniques. For more information see table (2).

This study proves not only the importance of evaluation methods that should be consistent and the necessity of combined method for a quantitative assessment of spatial improvement and spectral preservation. The idea of image fusion is to pan sharpen multispectral information, which is not the case if the spatial structures in the fused images are only slightly improved when compared to the original. Then the fused image looks very similar to the original one and produces excellent results in the statistical evaluations for color preservation. four techniques of image fusion have been achieved.

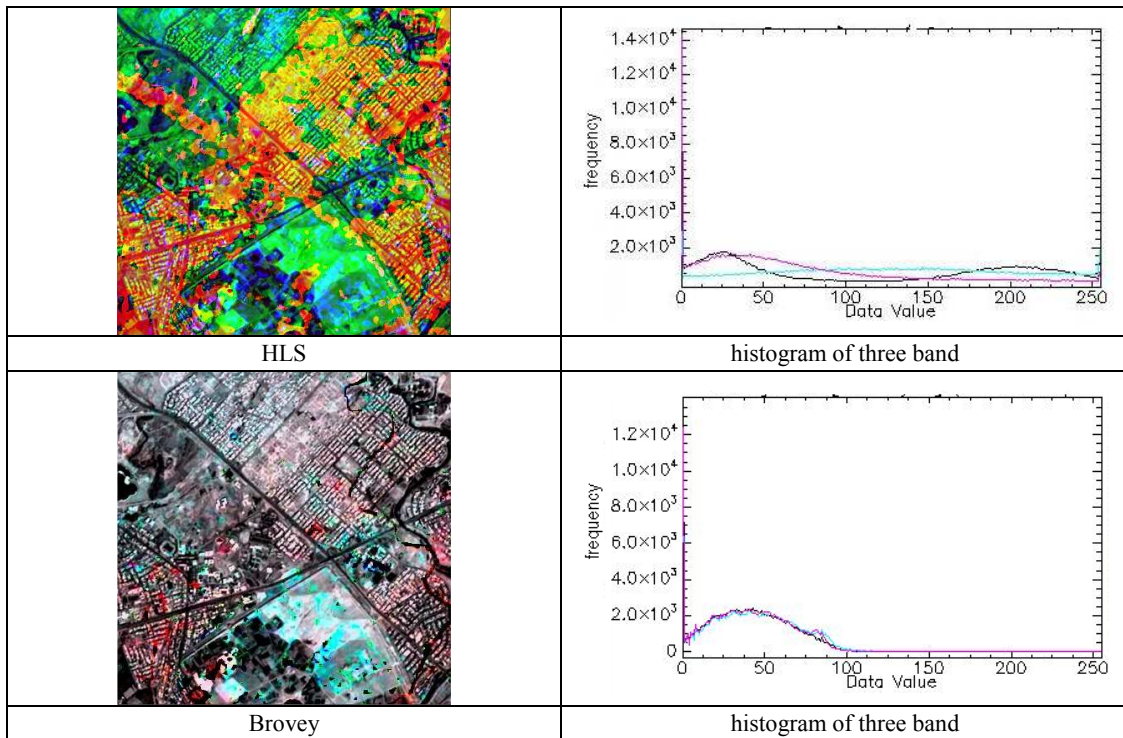


Figure 2- Show The Results Of Fused Images Using Hls And Brovey Techniques.

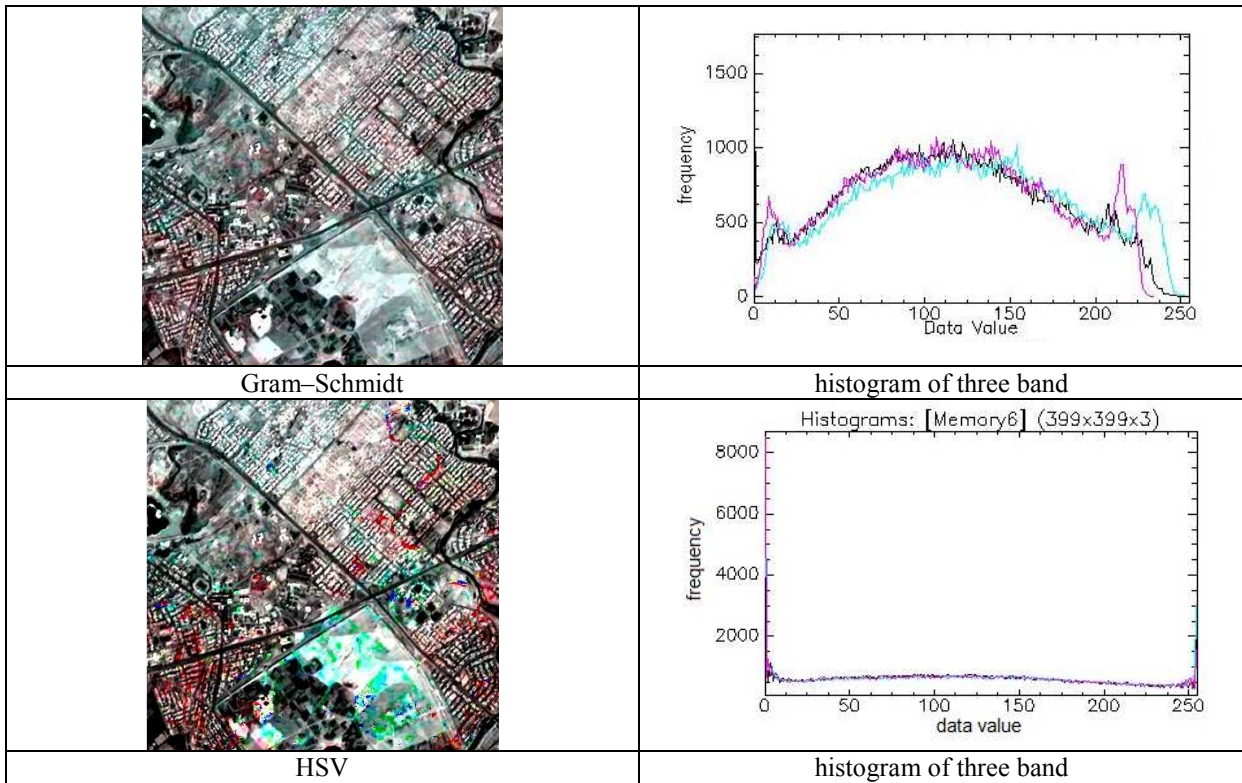


Figure 3- Show The Results Of Fused Images Using Gram-Schmidt And Hsv Techniques.

Table 2- Represent The Statistical Criteria Between The Original And Fused Image

Fusion methods	RMSE	PSNR	CC(correlation coefficient)
HLS	5.3218	21.9762	0.899
Brovoy	7.1280	16.1317	0.597
Gram-Schmidt	0.7745	60.5232	0.998
HSV	0.7502	17.2210	0.950

Table 3- Shows The Statistical Properties Of The Fusion Techniques.

Fused images	Bands	Min	Max	Mean	Std.dev.
HLS	Band1	0	255	107.285966	90.085156
	Band2	0	255	129.512371	69.501956
	Band3	0	255	63.04596	57.012458
Brovoy	Band1	0	255	39.850346	26.096062
	Band2	0	255	43.311694	27.448701
	Band3	0	255	40.785969	25.308641
Gram-Schmidt	Band1	0	255	113.948559	58.130039
	Band2	0	252	124.424131	60.939461
	Band3	0	234	115.101532	57.371996
HSV	Band1	0	255	115.979	73.9182
	Band2	0	255	119.4807	76.76
	Band3	0	255	114.5267	74.726

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