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Improve the Spatial Resolution of Multispectral satellite Image using Different Image Sharpening Techniques

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Abstract
The process of combining the significant information from a series of images into a single image called image sharpening or image fusing, where the resultant fused image will be having more spatial and spectral information than any of the input images. in this research two images of the same place in different spatial resolution have been used the first one was panchromatic and the second image was multispectral with spatial resolution 0.5m and 2 m respectively. These images were captured by world view-2 sensor. This research present four pan sharpening methods like (HSV, Brovey (color normalizes) , Gram shmidt and PCA)these methods were used to combine the adopted images to get multispectral image with high spatial resolution. Many criteria such as MSE, RMSE, PSNR, CC, ERGAS and RASE have been used to evaluate the quality of the result images.

Keywords: image fusing, Gram Shmidt, PCA

تحسين الدقة الحيزية للصورة الفضائية المتعددة الحزم بأستخدام تقنيات دمج صور مختلفة

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الخلاصة
عملية جمع المعلومات ذات المغزى العلمي من مجموعة صور ودمجها في صورة واحدة تسمى عملية الدمج، وذلك للحصول على صورة تحوي معلومات حيزية عالية بالاضافة الى المعلومات الطيفية مقارنة بالصورة الداخلة. في هذا البحث تم استخدام صورتين لنفس المكان لكن بدقة حيزية مختلفة، الصورة الاولى هي احادية والصورة الثانية متعددة الحزم بدقة حيزية 0,5 م و2م على التوالي. تم التقاط هذه الصورة بواسطة المتحسس(world view-2). قدم هذا البحث اربع طرق دمج مثل ,(HSV, Brovey(color normalize)) (Gram shmidt, PCA) استخدمت لدمج الصورة المتبناه للحصول على صورة متعددة الحزم ذات دقة حيزية عالية. تم استخدام عدة معايير جودة مثل(MSE, RMSE, PSNR, CC,ERGAS , RASE) وذلك لتقييم كفاءة الصورة الناتجة.

1. Introduction

Image sharpening is the process by which the relevant information has been combined from two or more images into a single image. The resulting image will be more informative than the set input images. This process is helpful for several purposes such as features surface objects and phenomena change detection, recognition, identification, tracking, classification, etc. These objectives may be encountered in many fields of study like remote sensing, robotics, medicine, space, environmental,

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urban planning, agricultural researches, etc. [1, 2]. A multispectral sensor captures several distinct wavelengths or bands for each spatial element or pixel. Hence, a multispectral image can be considered to consist of several layers where each layer contains the recorded a specified wavelength, or rather, a tight band of wavelengths. On the other hand, a panchromatic sensor records a broad continuous range of wavelengths, Due to cost and complexity issues, the multispectral sensor has much smaller aperture than the panchromatic sensor thus reducing the spatial resolution of the sensed multispectral image [3]. Since the multispectral image contains information about light of specific and narrow bands of wavelengths, it has a high spectral resolution and has low spatial resolution while the panchromatic image has a high spatial resolution. Pan-sharpening is the fusion of the images captured by the multispectral and panchromatic sensors. The output is an image that has the high spectral resolution of the multispectral image and also the high spatial resolution of the panchromatic image. In this research many pan-shappening methods such as (HSV,color normalize, Gram shmidt and PCA)have been employed to improve the spatial resolution of multispectral images. As well as many criteria have been adopted to show the quality of each method.

2. Methodology

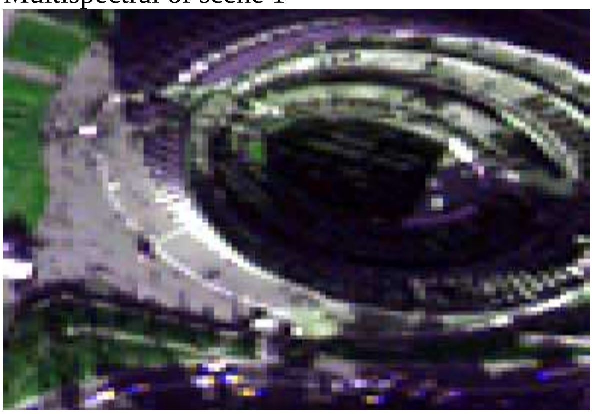
Table 1- The properties of world view-2 sensor [4]

	bands	Wavelength (nm)	bands	Wavelength (nm)
Sensor bands	panchromatic	400-800		
	8 multispectral			
	coastal	400-450	Red	630-690
	Blue	450-510	Red edge	705-745
	Green	510-580	Near-IR1	770-895
	yellow	585-625	Near-IR2	860-1040
Sensor resolution	Panchromatic	0.46m GSD at nadir, 0.52m GSD at 20^o off-nadir		
	multispectral	1.85m GSD at nadir, 2.07m GSD at 20^o off-nadir		

Panchromatic of scene1

Multispectral of scene 1

Panchromatic of scene 2



Multispectral of scene 2

Figure 1- panchromatic and multispectral of the original images captured by WV-2 sensor.

2.1 Hue saturation value (HSV) transformation [5]:

This can be achieved as following steps:

1. Register the low resolution multispectral image to the same size as the high resolution panchromatic image.
2. Three components of the original image R, G and B are transformed into the HVS color space.
3. The low-resolution Intensity component V is replaced by the panchromatic band with higher spatial resolution.
4. Transform the image back to RGB color space with the original values of H and S to obtain the fusing image as shown in Figures-(2, 3).

2.2 Brovey (Color Normalize)

Color normalized fusion or sometimes called Brovey transform, is depending on the chromaticity transform and intensity function. It can be used to merge the image data from different sensors, which can replace its brightness with the high spatial resolution panchromatic band, each of the three spectral components (as RGB components) is multiplied by the relative amount of a high-resolution co-registered image to the intensity component I of the multispectral bands. The mathematical algorithm for the Brovey method [6] can be given as:

$$CN_i = \frac{3*(A_i+1)*(B+1)}{\sum_i A_i+3} - 1 \quad (1)$$

Where A is multispectral image, B is panchromatic image and *CNi*, is the output color normalized band. The results fusing image by applying the brovey (color normalize) method can be shown in Figure-3 respectively.

2.3 Gram Shmidt transformation which can be applied as following:

1. Simulation process have done using the following formula [7].

$$B_{sim} = \sum_{k=1}^{n} W_k A_k \quad (2)$$

Where Wk is the weight of pixel and Ak is the multi-spectral image.

2. Apply a Gram-Schmidt transformation on the low spatial resolution image and high spatial resolution panchromatic band.

3. Replacing the high spatial resolution panchromatic band with the first Gram-Schmidt band.

4. Applying the inverse transformation of gram Shmidt to obtain the final fusing image as shown in Figures-(2, 3) respectively.

2.4 Principle Component Analysis

(PCA) has been used to merge panchromatic and multispectral images as following [8]:

1. Register the low resolution multispectral image to the same size of the high resolution panchromatic image. Apply PCA transforms on multispectral image to receive PC1, PC2, and PC3.

2. Replace the first component pc1 of multispectral bands by panchromatic band.

3. Apply Inverse transformation of PCA to obtain final fusing images shown in Figures-(2, 3) respectively.

3. Criteria

To evaluate the obtain results there are many metric have been adopted as follow:

3.1Root Mean Squared Error *(RMSE)*

Can be used to find the root value of the difference between the fusing and original images as following formula [9]:

$$RMSE = \sqrt{\frac{\sum_x \sum_i (A_i(x) - F_i(x))^2}{n \times m \times d}} \quad (3)$$

x = the pixel, (i) = the band number, (n, m) are image coordinates and d = bands number.

3.2 The relative average spectral error (RASE):

This criterion can give by the following formula [9]:

$$RASE = \frac{100}{M}\sqrt{\frac{1}{N}\sum_{i=1}^{N} RMSE^2(B_i)} \qquad (4)$$

M = mean radiance, N =spectral bands (B_i) of the original Multispectral bands.

3.3 Relative dimensionless global error in synthesis (ERGAS):

It's used to calculate the amount of spectral distortion in the image and it is given by the following formula [9]:

$$ERGAS = \frac{h}{l}\sqrt{\frac{1}{N}\sum_{N=1}^{N}\left(\frac{RMSE_n}{\mu_n}\right)^2} \text{---}(5)$$

Where $\frac{h}{l}$ the relative amount between pixel sizes of Panchromatic and Multispectral,μ_n is the mean of the nth band, and N is the number of bands. Best values less than 3[10].

3.4 Correlation Coefficient (CC)

The correlation coefficient is used for measuring the similarity of two datasets. The range of CC [-1 to 1] reach to 1 indicate a high similarity between the two compared images . The general Formula can be given as [11]:

$$Cc = \frac{\sum_{i=1}^{N}\sum_{j=1}^{N}(A_{i,j}-\bar{A})(F_{i,j}-\bar{F})}{\left[\sum_{i=1}^{N}\sum_{j=1}^{N}(A_{i,j}-A)^2 \sum_{i=1}^{N}\sum_{j=1}^{N}[(F_{i,j}-F)^2]^{1/2}\right]} \qquad (6)$$

Where A is original image and F is fused image. All the results metric can be shown in Tables-(2, 3) respectively.

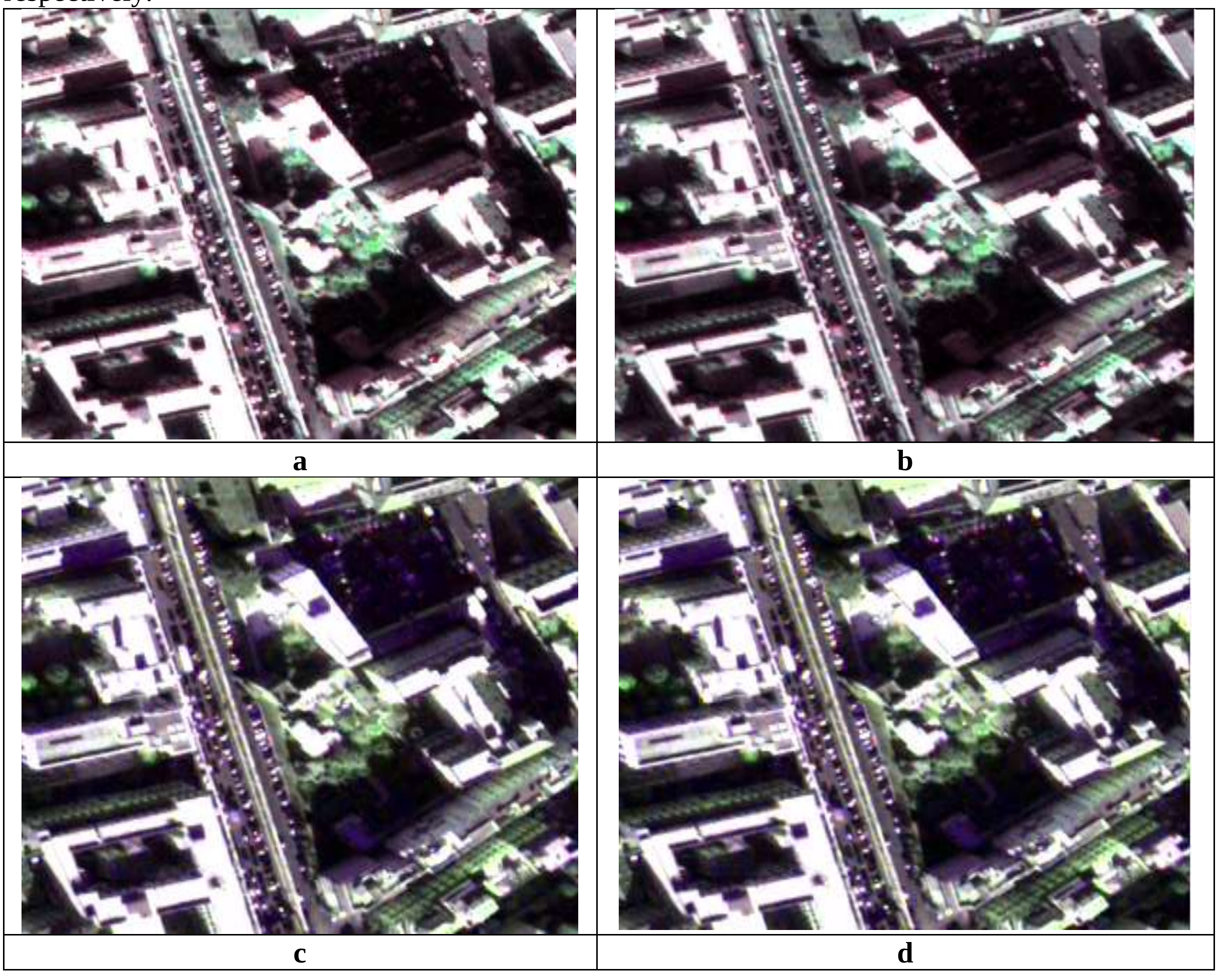


Figure 2- The results of fused image for scene 1 using a) HSV b) Brovey (color normalize) c) Gram-Shmidt d) PCA.

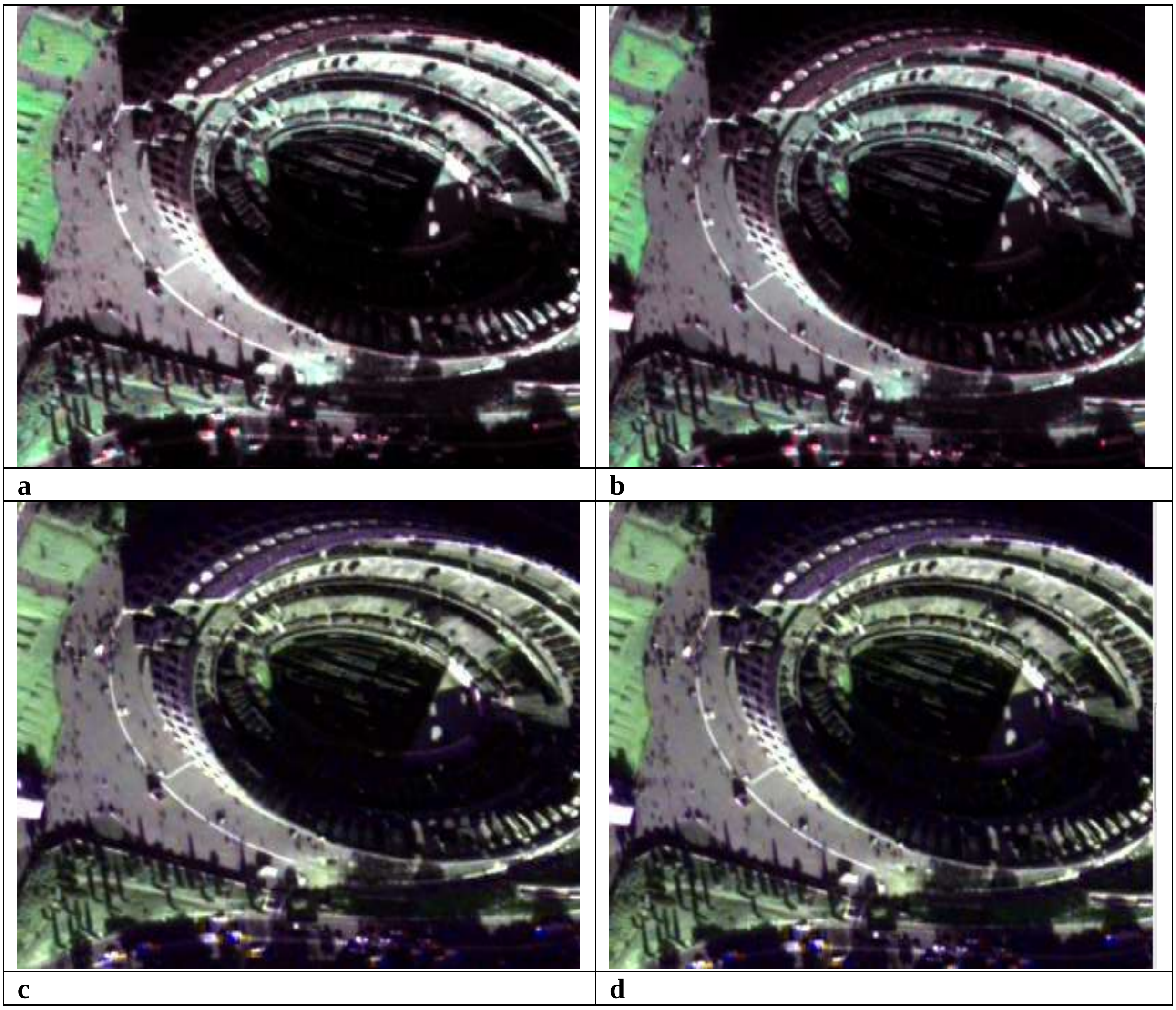


Figure 3- The results of fused image for scene 2 using a) HSV b)Brovey(colornormalize) c) Gram-Shmidt d) PCA.

4. Discussion and conclusion

The goal of applying image sharpening is to improve the spatial resolution of the multispectral images while preserving their spectral contents. So there are many quality metric have been used to compare between the results fused images and original panchromatic image in one hand and with original multispectral image in the other hand. All the metric show that the results fused image is more correlated with the original panchromatic image. From the statistical computations of six quality metric as shown in Table- 2 and Table- 3 it is easy to estimate that the results fused image have the same properties of the high spatial resolution of panchromatic band than the low spatial resolution of multispectral image, where the values of mean square error (MSE), root mean square error (RMSE), ERGAS and RASE have been increased and Peak signal to noise ratio (PSNR) and correlation coefficient (CC) have been decrease in case of the comparison between the fusing images and the original multispectral image. in the other hand the quality metric in Tables- 2 and 3 give inverse behavior when the comparison have been done between the fusing image and panchromatic image, the conclusion of applying different pan-sharpening methods show that the spatial resolution of the resultant fusing image have been improved and the multispectral image have high spatial resolution as well as high spectral resolution. Also the result show that HSV and GramShmidt methods give less error or less (MSE) and more (PSNR) than other fusing methods

Table 2- the criteria between the panchromatic images with the fusion images.

method	Criteria					
	MSE	RMSE	PSNR	ERGAS	RASE	CORR.
HSV	22.1422	4.705	34.678	1.4285	12.322	0.968
Color normalize	46.832	6.8434	31.425	2.3296	7.527	0.977
Gram-Shmidt	40.174	6.338	32.091	2.1207	7.9098	0.9817
PCA	44.684	6.684	31.629	2.2633	7.486	0.9814

Table 3- the criteria between multispectral images with result fusion images.

method	Criteria					
	MSE	RMSE	PSNR	ERGAS	RASE	CORR.
HSV	70.586	8.401	29.643	2.5506	14.217	0.8167
Color normalize	85.864	9.266	28.792	3.154	12.986	0.8208
Gram-Shmidt	82.261	9.069	28.978	3.034	12.958	0.815
PCA	85.712	9.258	28.8	3.134	12.767	0.818

References

1. Pohl, C. and Van Genderen, J. L.**1998** Multisensor image fusion in remote sensing: concepts, methods and applications, *International Journal of Remote Sensing*, **9**(5): 823-854.
2. Dasarathy, B. V. **1993**. Decision fusion. *IEEE Computer Society Press, Los Alamitos*, CA, USA. **21**(5): 1140-1154.
3. Gary, A. S. and Hsiao, K. **2003**. Spectral imaging for remote sensing. *Lincoln Laboratory Journa*l, **14**(1): 3–28.
4. www.digitalglobe.com, Corporate (U.S.) 303.684.4561 or 800.496.1225 | London +44.20.8899.6801 | Singapore +65.6389.4851
5. Adrian.F and Alan. R, **1998**. Color Space Conversions *".IEEE Geoscience and Remote Sensing Letters*, **6**(4): 522-546.
6. Vrabel, J. **1996.** Multispectral Imagery Band Sharpening Study. *Photogrammetric Engineering & Remote Sensing*, **62**(9): 1075-1083.
7. Maurer, T. **2013**. How To Pan-Sharpen Images Using The Gram-Schmidt Pan-Sharpen Method – A Recipe, International Archives of the Photogrammetry. *Remote Sensing and Spatial Information Sciences*, XL-1/W1, ISPRS Hannover Workshop, 21–24 Hannover, Germany.
8. Loeve, M. D. van Nostrand Co., Princeton, Nj. Luo, R. C., & Kay, M. G.**1989**. Multisensor integration and fusion in intelligent systems, *IEEE Transactions on SMC*, **19**(5): 905-912.
9. Melissa, S., Sheida, R., and Daria, M. **2008**. Evaluation of Pan-Sharpening Methods, *IEEE Geoscience and Remote Sensing Letters*, **7**(4): 746-750.
10. Shivsubramani, K. and Soman, K. P. **2010**. Implementation and Comparative Study of Image Fusion Algorithms. *International Journal of Computer Applications*, **9**(2): 0975 – 8887.
11. Swain, P. H. and Davis .S. M. **1978**. *Remote Sensing: The Quantitative Approach*, 1st Edition, New York: McGraw-Hill, 396.