Satellite Images Fusion Using Modified PCA Substitution Method

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Abstract

In this paper, a new tunable approach for fusion the satellite images that fall in different electromagnetic wave ranges is presented, which gives us the ability to make one of the images features little superior on the other without reducing the general resultant image fusion quality, this approach is based on the principal component analysis (PCA) fusion method. A comparison made is between the results of the proposed approach and two fusion methods (they are: the PCA fusion method and the projection of eigenvectors on the bands fusion method), and the comparison results show the validity of this new method.

Key Words: Fusion, PCA, Eigenvectors, Substitution.

Introduction

Remote sensed images play a great deal in the earth resources and monitoring. due to the variety of sensors that are carried on the satellites, which rise a problem of analysis of the huge amount of data that are acquired through these sensors. one of the effective methods to analysis is through fusion techniques, in which two or more images (bands) are fused to create single gray scale image that catty the information of these images. The side effect of the fusion process is that some of information of the fused image are lost compared with final product, therefore, the effective fusion techniques are these that keep a balance (or an almost balance) portion of information of the fused images into the final product. [1]

Fusion techniques can be classified mainly into two kinds, fusion of low spatial resolution multispectral satellite image with high spatial resolution one band satellite image to produce high spatial resolution multispectral image. This technique is well known and there is sufficient of literature published about it. [2] The second kind of fusion technique is the fusion of two satellite image which belongs to two different portions of the electromagnetic spectral rang, which usually came with dramatically different information (inconsistent or complementary information), beside that the statistics of the image which are also differ. [3]

Acquiring images from different sensors that work in two different portions of electromagnetic wave range that produce distinct images for the same scene, in which, they may contain different information or features. for example, if we use two sensors one work in the radar waves and the second in the visible light, usually, the radar image may contain significant features that are absent in the visible light image, beside that the radar image will be high contrast low details image comparing with the visible light image which will be high details low contrast image. [3]

Fusing images that differ dramatically in nature (contrast, brightness, standard deviation...), such like fusing radar wave image with visible light image, will produce poor quality images since the high contrast image will dominate on the other. [4]

Principal component analysis (PCA) is one of the techniques that used fuse number of bands to one gray scale image. There are two approaches to fuse these bands [4]:

1. PCA of all multi-image data channels.

2. Project the eigenvectors (a_{kp} for band k and component p) on the bands brightness value (BV) as a loading factor according to the following equation [5]:

$$\boldsymbol{newBV_{i,i,p} = \sum_{k=1}^{n} a_{k,p} BV_{i,j,k}} \quad \ldots (1)$$

The first approach procedure integrates the disparate natures of multi-sensor input data in one gray scale image, and that can be achieved by perfuming the PCA transform on the images and take the first principle as the fused image since it represents the common features in the fused images. [4]

The second approach tries to remap the brightness value according to the variance of the bands, where the eigenvector is used as a loading factor producing a new representation for the bands brightness for each principle component. [5]

The problem with these two methods is that there is no way to tune the fused images to maintain balance the information that combined from these images to produce a single image, or to determine which of the fused images should slightly dominate on the fused image.

In this research work, the attention focused on the problem of image fusion in remote sensing: the combination of mages from optical VL, visible near infrared VNIR, and SAR

(Synthetic Aperture Radar) sensors taken for the same scene on the Earth's surface to achieve better information-extraction capabilities over features of interest in the observed scene.

The Proposed Fusion Algorithm

To provide a new fusion method of better quality fusion performance, with a capability of tuning the fusion process to make one of the fused bands features slightly higher than the other, this paper introduces a new fusion method based on the PCA analysis.

To apply PCA transform on one band only, a new procedure is proposed in which one band (usually the band with high resolution) is expanded to three bands as a vector using scaling factors, one of the scaling factors must be equal to one

$$\boldsymbol{Band_i = \alpha_i * Band}, \qquad \boldsymbol{0 < \alpha_i \leq 1} \qquad \ldots (2)$$

then decompose the new three bands using the PCA and replace the second and third components together and leave the first component intact then restore the fused image by applying the inverse for the PCA transform and the band of scaling factor equal to one considered as fusion image, (see figure 1). To fuse different bands that differs dramatically in the wavelength (like VL with SAR and VL with VNIR), it is preferably to use the correlation matrix in the PCA analysis, because it gives each band a unit of variance so that none of the bands features would dominate on the other in the resultant fused image.

Using this procedure will give the band features, that decomposed using the scale factors, little superiority on the other without reducing the features in the band that substituted instead of the second and third component, this superiority for the decomposed band came from the fact that the major information is in the first component of the PCA analysis since we kept it for the decomposed band therefore its feature will be more apparent than the features of the substituted band.

Experiment Results

The proposed method had been validated by fusing three images for the same location, which represents Baghdad international airport, one of them is taken in microwave band (Advance Synthetic Aperture Radar ASAR) by ENVISAT satellite and the two other images fall in the optical range, see table 1. Even the two optical images, but one of them is taken at 7:45:31 am by IRC-1C in the winter (2001:12:7) where the sun raise at that day is at 6:52 am therefore the image contains thermal information more than the optical since the ground is stile cold and the mineral material becomes hotter; while the second image is taken at 3:41:51 pm by IKONOS and since this image taken in the afternoon where the surface of the ground have equal temperature therefore it has no thermal information and it represents a pure visible reflection information. For that the IRC-1C image in this research will be considered and will be referred to as VNIR and the IKONOS image will be referred to as VL.

Since the three images differ in the spatial resolution. At first we registered these three images accurately with root mean square error less than half pixel. To validate the proposed algorithm, it had been applied to fuse different images. firstly by fusing the VL with VNIR, once, where the VL image expand to three bands to make its features little superior over the VNIR image, and once the VNIR image expand to three bands to make its features little superior over the VL image, and secondly by fusing the VL with ASAR, once where the VL image expand to three bands to make its features little superior over the ASAR image, and once the ASAR image expand to three bands to make its features little superior over the VL image, the value of scaling factor α_i is chosen as (1, 0.5 and 0.25). The results are compared with the two fusion method mentioned in section 1, that is validated to fuse two images (the second and third method).

To make a subjective comparison beside the visual comparison, and to force the comparison to be between the images details (high frequency) in order to reduce the error that came from the differences in the images brightness, the images were eliminated from their mean, then the SNR was calculated for the zero mean images. The result of comparison of the fused images produced by applying the different method on fusing the VL with VNIR and VL with ASAR, which are shown in tables 2 and 3.

Figures 2 & 3 show the fused results were produced by applying the above methods to fuse VL with VNIR and VL with ASAR, where sub images (a) and (b) are the original images, VL and (VNIR/ASAR) images respectively, sub image (c) shows the result of fusing the two images using band expanding (VNIR/ASAR superior to VL), while sub image (d) shows the result of fusing the two images using band expanding (VL superior to VNIR/ASAR), sub image (e) shows the result of applying the first principle fusing method and sub image (f) shows the result of fusion method projecting (remapping) the eigenvector values on the bands. What should be mentioned is that in the first principal fusion method the negative process had been applied to the resultant image.

Conclusion

The results (table 2 & 3) of applying the proposed approach and compare their results with two standard fusing methods, show that the proposed fusion method produce better fusing images quality than the method of projecting the eigenvector on bands, while the mean of the fusing image quality of the proposed method is higher than the result of taking the first principle fusion method but with advantage of tenability. As shown in the results when we make one of the images superior the degradation in the other image features is small (about 2 dB) comparing with the superior image. The new fusion method validated using different images that differ in their images features (texture, contrast, and brightness), which make this method more reliable to fuse images independent on the differences between images features.

References

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Table(1) The characteristics of the test images

Satellite	Spectral Coverage	Spatial Resolution	Radiometric Resolution	Frame size	Date	Time
IRC-1C	0.5-0.90	5.5	8	900x650	2001:12:7	07:45:31
IKONOS	0.45-0.90	1	8	3450x4600	2003:04:02	15:41:51
ENVISAT	HH VV VV/HH	30	8	4249x4386	2003:2:24	12:12:42

Table(2) The SNR of the zero mean results VL with VNIR

Fusion method	Zero Mean SNR (dB)	
	to SAR	To VL
First principle fusion	10.3	10.3
Eigenvectors projection on bands fusion	5.9	7.3
Band expanding (VL superior on VNIR)	9.5	11.1
Band expanding (VNIR superior on VL)	12.1	8.8

Table(3) The SNR of the zero mean results of fusing VL with ASAR

Fusion method	Zero Mean SNR (dB)	
	to SAR	To VL
First principle fusion	4	4.6
Eigenvectors projection on bands fusion	2.7	3.9
Band expanding (VL superior on ASAR)	3.9	4.4
Band expanding (ASAR superior on VL)	7	2.3

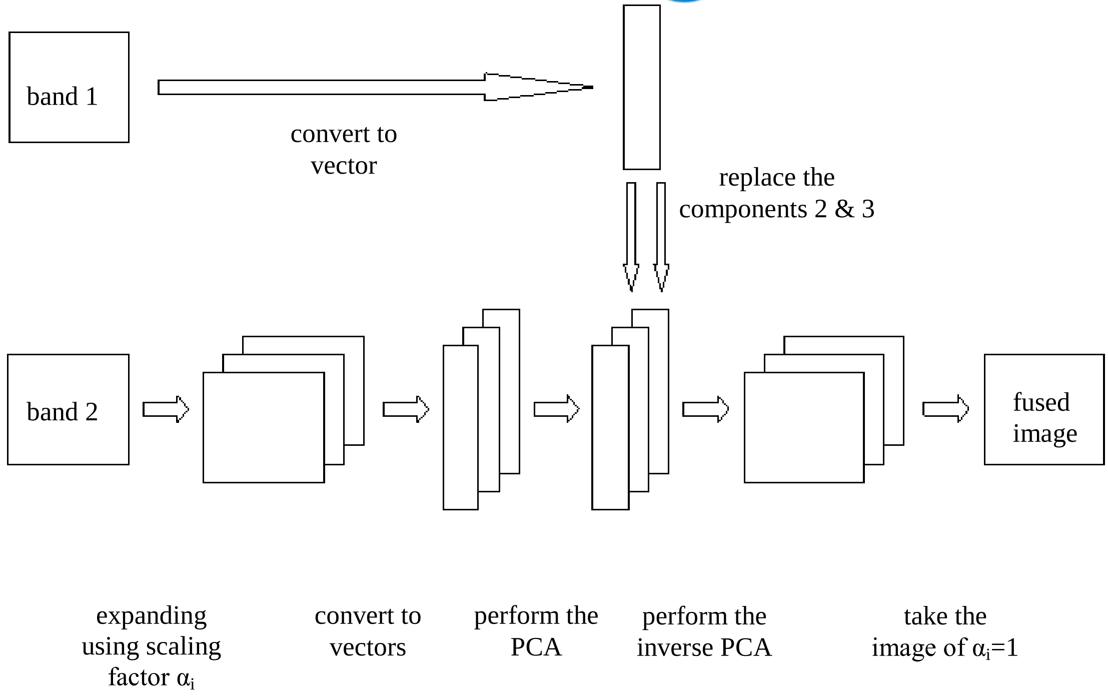

Figure (1) The proposed method to fuse two images belong to different electromagnetic wave bands by expanding one of them to three bands using scaling factors.

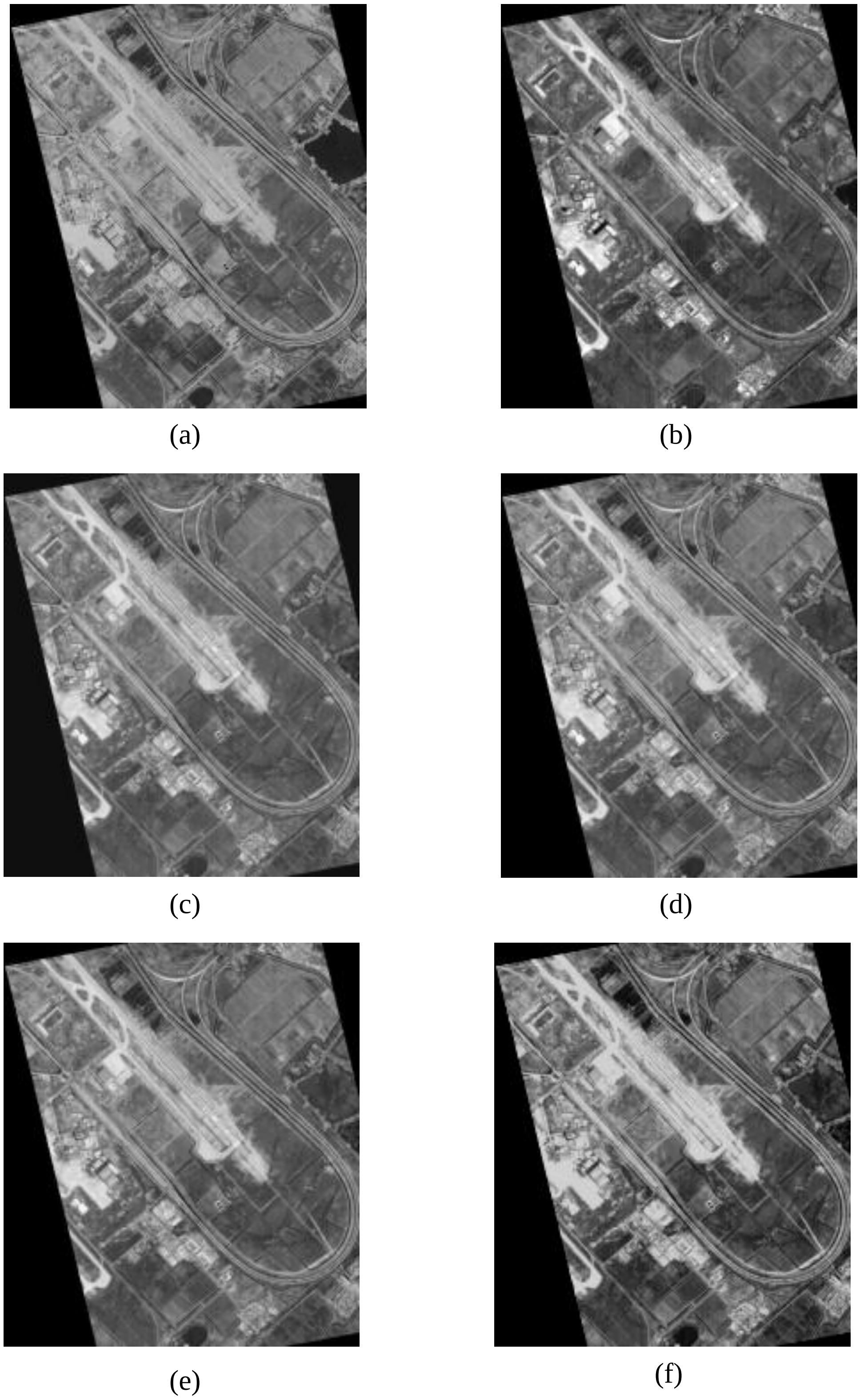

Figure (2) Image of airport taken by two different satellites; (a) via IKONOS; (b) via IRS-1C; (c) fused image by band expansion (VNIR superior to VL); (d) fused image by band expansion (VL superior to VNIR); (e) fused image by taking the first component; (f) fused image by projecting the eigenvector on bands.

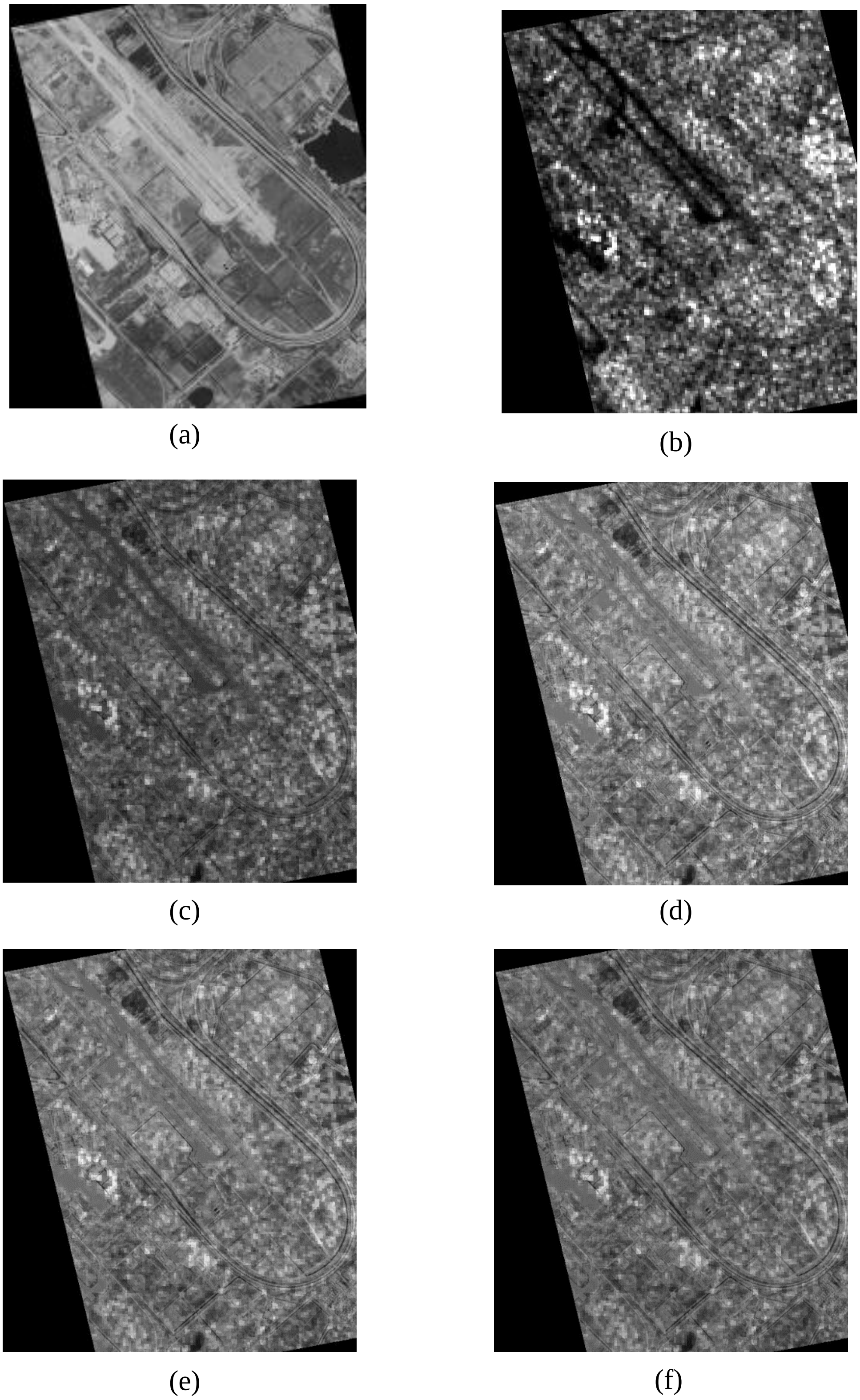

Figure (3) Image of airport taken by two different satellites; (a) via IKONOS; (b) via ENVISAT; (c) fused image by band expansion (ASAR superior to VL); (d) fused image by band expansion (VL superior to ASAR); (e) fused image by taking the first component; (f) fused image by projecting the eigenvector on bands.

صهر الصور الفضائية بوساطة تحويل المركبات الأساس المعدل بالطريقة الابدالية

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الخلاصة

في هذا البحث طريقة جديدة قابلة للتعديل لأجل صهر الصور الفضائية التي تقع ضمن مديات مختلفة من طيف الاشعة الكهرومغناطيسية، والتي تعطينا الامكانية لجعل خصائص أحدى الصور تتفوق بشكل قليل على الأخرى من غير ان تتدنى نوعية الصور الناتجة من الانصهار بشكل عام، هذه الطريقة تستند إلى تحويل المركبات الأساسية. تم اجراء مقارنة بين نتائج الطريقة المقترحة وطريقتي دمج أخرى (والتي هي: طريقة تحويل المركبات الأساسية وطريقة اسقاط القيم الذاتية على الحزم)، وبينت نتائج المقارنة صحة الطريقة الجديدة.

الكلمات المفتاحية: صهر، تحويل المركبات الأساس، المتجهات الذاتية، الابدالية.