A New Image Fusion Technique to Improve the Quality of Remote Sensing images

A. El Ejaily[1], F. Eltohamy [2] , M.Y. EL Nahas [3] and G. Ismail [2]

[1] **MTC**
Cairo/ Egypt

[2] **Egyptian Armed Force**
Cairo/ Egypt

[3] **Alazhar University**
Cairo/Egypt

Abstract

Image fusion is a process of producing a single fused image from a set of input images. In this paper a new fusion technique based on the use of independent component analysis (ICA) and IHS transformation is proposed. A comparison of this new technique with PCA, IHS, and ICA-based fusion techniques is given. Quick Bird data are used to test these techniques, the output was evaluated using subjective comparison, statistical correlation, information entropy, mean square error, and standard deviation. The results of the proposed technique show higher performance compared to the other techniques.

keywords: *Image fusion, principle component analysis(PCA), Independent component analysis(ICA), Intensity Hue Saturation(IHS).*

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 [1].

Many techniques and software tools for fusing images have been developed [2-4]. From the well-known methods the Brovey method, the intensity–hue–saturation (IHS) , principal component analysis (PCA), and discrete wavelet transform (DWT). Although these methods (IHS, PCA, and Brovey transform)
provide us with fused images with high spatial resolution, but they suffer from spectral distortion that introduced during the fusion process.
The invention of multi-resolution analysis tool like wavelet transform allow us to further improve the quality of the fused image, but it needs a proper selection of decomposed level according to the ratio between the PAN and MS images .The former studies show that we can use independent component analysis (ICA) to achieve a fused image with a high spatial resolution and minimum spectral distortion [5,6].
The ICA-based remote sensing image fusion is performed by transform the MS image into its independent components then the most significant IC is replace by PAN image and then an inverse ICA is performed on the new combination to retain the fused image. the author in [7] used wavelet transform to improve the performance of ICA-fusion technique.
In this paper we propose a new approach based on the use of IHS transform and ICA to improve the ICA performance in the fusion of remote sensing images. First the MS and PAN images are fused using a classical ICA method to get intermediate fused image then we use IHS transform to transform the resultant fused image together with the original MS image to IHS color space
in the last step inverse IHS is applied to color components - H & S- of MS image and the intensity component of the intermediate fused image.

2. Concept of Independent Component Analysis.

ICA is a computational method for separating a multivariate signal into additive subcomponents supposing the mutual statistical independence of the non-Gaussian source signals[8].
The estimation of the data model of independent component analysis is usually performed by formulating an objective function and then minimizing or maximizing it. Therefore, the properties of the ICA method depend on both the objective function and the optimization algorithm. assume that there is an M-dimensional zero mean vector $S = (S_1, S_2, \dots, S_M)^T$,

whose components are mutually independent distributions

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$$p(s) = \prod_i^M p_i(S_i) \qquad (1)$$

a data vector $x = (x_1, x_2, \ldots, x_N)^T$ is observed vector at point t , such that

$$s(t) = Ax(t) \qquad (2)$$

where, A is an N*M scalar matrix which is called mixing matrix.
The goal of ICA is to find a linear transformation *W* of the correlative signal *x* that makes the outputs as independent as po

$$u(t) = Wx(t) = WAs(t) \qquad (3)$$

Where, u is an estimate of the sources.

3. Image fusion algorithm based on ICA-IHS

Although the main significant IC contains the main content of color image, the spectral and spatial information of the color image is not completely separated. Some of spatial information are also located in the other ICs. Therefore, the ICA- based fusion method tends to produce a fused image with high spatial detail, but also may lead to spectral distortion in some local regions. To minimize this spectral distortion we use IHS transform to further process the resultant fused image and replacing its color components with that of original MS image.
This is the central idea of the improved ICA fusion method. Figure 1 outlines the general procedure to fuse MS and PAN images using the improved ICA method based on IHS, and the detailed steps of ICA-IHS fusion method are as follows:
(1) Registering the MS and the PAN images with the error pixel.
(2) Applying ICA to MS bands to transform the correlated band to a linear combination of independent components.
(3) The most significant component of step (2) is replaced with PAN image, then the intermediate fused image is obtained by inverse ICA.
(4) To overcome the spectral distortion of the intermediate fused image, we transform this fused image and the original MS image to IHS color space and we replace the color components (hue & saturation) of the intermediate fused image with that of original MS image
(5) At last the final fused image is obtained by inverse IHS of the new combination of step (4).

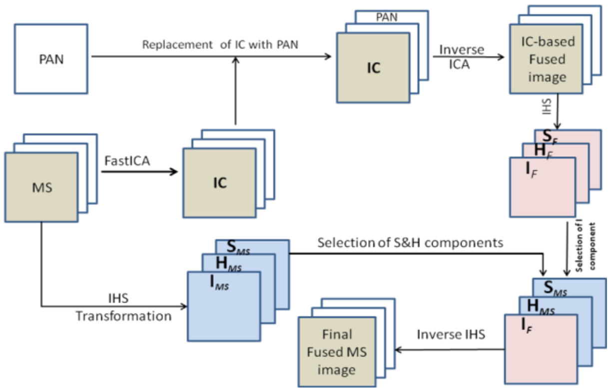


Fig. 1. the flow diagram of the proposed image fusion method.

3. Quality Assessment Criteria

Quality refers to both the spatial and spectral quality of images [9]. The goal of image fusion is to increase the spatial resolution of the MS images while preserving their spectral contents. In this paper we use correlation and discrepancy to assess the spectral quality of the fused image, while for the measurement of spatial quality we use the high-pass correlation and entropy.

3.1 spectral quality assessment:

For a good spectral fidelity of the fused image, the low spatial frequency information in the high-resolution image shouldn't be transferred to the fused image. The following measures are used to test the spectral quality of the fused image:

3.1.1 correlation coefficient(CC):

CC measures the correlation between the original MS image and the fused images. The higher the correlation between the fused and the original images, the better the estimation of the spectral values [10]. The ideal value of correlation coefficient is 1.
The formula to compute the correlation between two images A&B is given by:

$$Corr(A/B) = \frac{\sum_{i=1}^{N}\sum_{j=1}^{M}(A_{i,j}-\bar{A})(B_{i,j}-\bar{B})}{\sqrt{\sum_{i=1}^{N}\sum_{j=1}^{M}(A_{i,j}-\bar{A})\sum_{i=1}^{N}\sum_{j=1}^{M}(B_{i,j}-\bar{B})}} \qquad (4)$$

Where $\bar{A}$ and $\bar{B}$ are the mean values of the corresponding data set, (i,j) denotes a given pixel, N&M are the image dimension.

3.1.2 discrepancy:

The spectral quality is measured by the discrepancy D_k, at each band as follows:

$$D_k = \frac{1}{M * N}\sum_{i=1}^{M}\sum_{j=1}^{N}\left|F_{K,i,j} - MS_{K,i,j}\right|$$

$$K = R, G, B \qquad (5)$$

Where $F_{K,i,j}$ and $MS_{K,i,j}$ are the pixel values at position(*i*,*j*) in the *Kth* band of the fused and original MS image, respectively. It is known that the spectral quality of the image increases as *DK* decreases[11].

3.1 Spatial quality assessment:

For a good spatial fidelity of the fused image, the high spatial frequency information in the high-resolution image(that represent image edges) should be transferred to the fused image. The indexes which can reflect the spatial fidelity of fused image include:

3.2.1 High pass correlation:

The spatial quality is obtained by computing the correlation coefficient, *CK*, between the high pass component of the fused image bands and the original PAN image. The high pass component is used in the evaluation of this criterion because the spatial information is mostly concentrated in the high frequency domain. The spatial quality of the image is directly proportional to *CK*[12]. To extract the high frequency data we apply the following convolution mask to the images:

$$mask = \begin{vmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{vmatrix} \qquad (6)$$

3.2.1 Entropy:

The Entropy(EN) can show the average information included in the image and reflect the detail information of the fused image [10]. The greater the Entropy of the fused image is, the more abundant information included in it, and the greater the quality of the fusion is. According to the information theory of Shannon, The image entropy is given by:

$$EN = -\sum_{g=0}^{L-1} p(g)\log_2 p(g) \qquad (7)$$

Where p(g) is the probability of grey level g, and the range of g is [0,...,L-1]. And L is the maximum value of the gray levels.

4. Experimental results and discussion

The QuickBird data were selected for carrying out the experimental work of this study, which were acquired on June 2006. the site were located in Tripoli, Libya. The images are composed of MS image with spatial resolution of 2.44m and PAN image with spatial resolution of 0.6 m. A sub-images of 1000 x 1000 pixels have been considered. Figure 2(a) and figure 2(b) shows the MS and PAN image respectively.

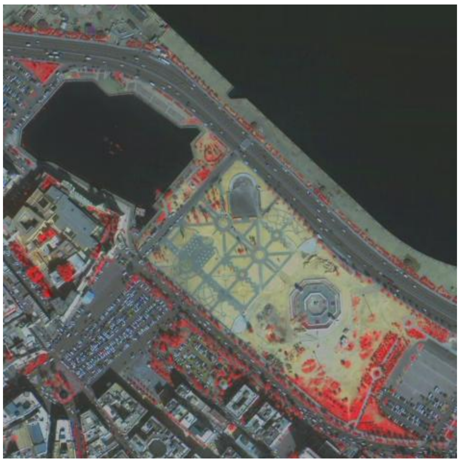
(a)

(b)

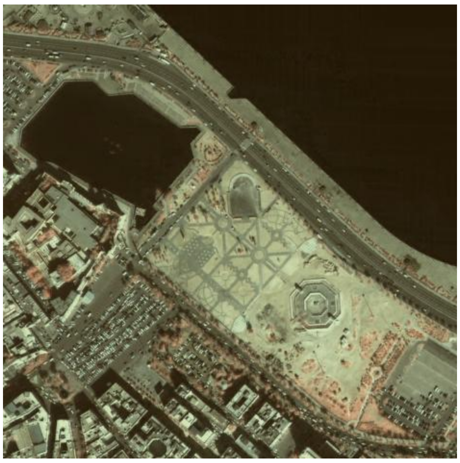
Fig. 2. QuickBird data of Tripoli (a) MS image; (b) PAN image

In order to examine the performance of the proposed image fusion method, we compare it with other fusion methods like IHS, PCA, and ICA. The resultant fused images are shown in figure 3.

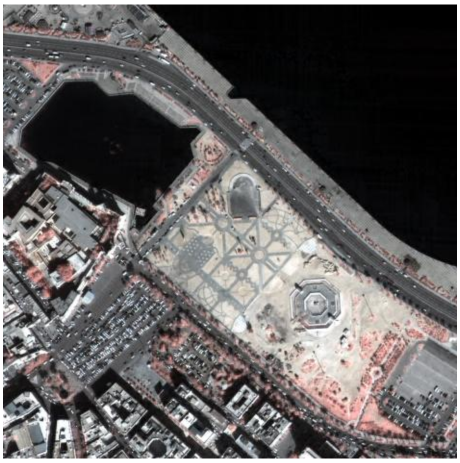
(a)



(b)



(c)



(d)

Fig. 3. The results of different fusion methods using QuickBird data (a)fused image by IHS; (b) fused image by PCA; (c) fused image by ICA; (d) the fusion result of applying the proposed method.

The visual inspection of the obtained fused images shows that all fusion methods retained an acceptable amount of spatial detail, the PCA method preserves fewer details than IHS. we get a maximum spatial detail in the fused image when we use ICA, but the distortion of the original color is very obvious . The improved ICA method proposed in this paper can solve this problem effectively, and we can achieve a fused image with a better balance between spectral characteristic preservation and high spatial resolution

To objectively assist the spatial quality of the obtained fused images we measure the high-pass correlation coefficients(C_k) and the information entropy (*EN*), the results of those two measure are shown in table 1, the results show that a fused image with a maximum spatial details is achieved when we used the improved ICA method. To assess the spectral quality we use the measurements of spectral discrepancy(D_k) and correlation coefficients (CCs). Table 2 shows the results which indicates that the improved ICA and IHS methods have almost the same spectral quality better than the other fusion techniques.

Table 1. The results of spatial quality assessment.

Fusion method	C_k			EN		
	R	**G**	**B**	**R**	**G**	**B**
PCA	0.7838	0.8185	0.7640	6.7397	6.6563	6.7061
IHS	0.9343	0.8969	0.8933	7.4069	7.4019	7.3456
ICA	0.8376	0.9309	0.8616	6.9958	7.1663	7.0015
proposed method	0.9269	0.9756	0.9550	7.5223	7.4881	7.5161

Table 2. The results of spectral quality assessment.

Fusion method	D_k			CC		
	R	G	B	R	G	B
PCA	0.1343	0.1330	0.1213	0.9314	0.9298	0.9338
IHS	0.0685	0.0690	0.0679	0.9706	0.9710	0.9680
ICA	0.1144	0.1152	0.1182	0.9527	0.9454	0.9083
Proposed method	0.0677	0.0902	0.0787	0.9714	0.9517	0.9552

5. Conclusion

In this paper we present an improved ICA image fusion method. In the convenient way of ICA-based image fusion, the most significant IC is replaced with PAN image then the fused image is obtained through an inverse ICA. This fused image is further processed by transform it to IHS color space. Then we select the intensity component together with color components (H and S) of the original MS image to produce a new fused image using inverse IHS transformation. Such new fused image will contain the original color with a high spatial detail. The QuickBird images were used to show the performance of the proposed method. The results show that the proposed method can preserve abundant spectral information and higher spatial resolution, and has a better performance compared with other techniques.

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