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IMAGE FUSION ALGORITHM FOR FUSION OF PANCHROMATIC AND MULTISPECTRAL IMAGES FOR HIGH SPATIAL INFORMATION WHILE PRESERVING SPECTRAL INFORMATION CONTENT

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Abstract:

In this paper image fusion algorithm for enhancing spatial quality of the multispectral image while maintaining the spectral quality of the multispectral image is proposed. The fusion algorithm is developed based on high frequency components injection to the multispectral image to improve the spatial quality of the fused image. High frequency component is generated using the Laplacian filter. Construct the saliency map and initial weight map. Finally optimum weight parameter is calculated for each band using the guided filter, using this optimum weight parameter panchromatic and multispectral images are fused to enhance the spatial quality of the multispectral image.

Key Words: Hybrid, Spatial, Spectral, Multispectral, Optimum, Filter & Weight

1. Introduction:

Many existing satellites like IKNOS, KOMPSAT-2, World View-2, Quick Bird, Geoeye-1 capture the real world images using panchromatic and multispectral sensors [1]. The panchromatic image obtained from panchromatic sensors is characterized as high spatial resolution and low spectral resolution. The multispectral image obtained from multispectral sensor is characterized as high spectral resolution and low spatial resolution. In many image processing tasks such as change detection, image classification, weather forecasting, a multispectral image with high spatial and high spectral resolution is desirable. Image fusion is technique used to produce the high spatial and high spectral image by fusing the low spatial high spectral multispectral image with low spectral high spatial panchromatic image [2].

There are four categories of image fusion algorithms 1) Ratioing methods 2) ARSIS methods 3) Model based methods 4) Component substitution methods.

- ✓ Rationing methods: these methods calculate synthetic ratio by using image divisions and then multiply ratio with the multispectral image.
- ✓ ARSIS methods: these methods calculate high frequency information from panchromatic image and inject in to the multispectral image.
- ✓ Model based methods: these methods construct a degradation model and renovate the high resolution multispectral image by the degradation model.
- ✓ Component substitution methods: these methods use transformations to estimate the gray values of the multispectral image in to the new space and then replace the components of the multispectral image in the new space by the panchromatic image [3], [4].

Out of all four methods the component substitution methods like Intensity Hue Saturation (IHS), Principal Component Analysis (PCA), Gram-Schmidt (GS), generalized component substitution methods (GCS) produce good fusion results and perform fast calculations. But the component substitution methods improve the spatial quality but have common limitation that unable to maintain spectral quality and introduce some spectral distortions. The paper is organized as section II gives fusion algorithm with Guided filter, section III gives results and comparison of existing methods, section IV gives the conclusion.

2. Fusion Algorithm using Guided Filter (FGF) [5]

Step 1: Read the panchromatic and multispectral source images.

Step 2: Decompose the panchromatic and multispectral images into base layer and detail layer.

$$M_n = I_n * A \quad (1)$$

$$N_n = I_n - M_n \quad (2)$$

Where, I_n is the n^{th} source image, A is the mean filter of of size 31 x 31.

Step 3: Generate the high frequency component by applying the Laplacian filter on each source.

$$H_n = I_n * L \quad (3)$$

Where, L is the Laplacian filter.

Step 4: Construct the saliency map.

$$S_n = |H_n| F_{r_g,\sigma_g} \quad (4)$$

Step 5: Normalize the saliences in to [0-1].

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Step 6: Construct the initial weight maps.

$$O_n^k = \begin{cases} 1, \text{if } S_n^k = max\{S_1^k, S_2^k, S_3^k, S_n^k\} \\ 0, \quad \text{otherwise} \end{cases} \tag{5}$$

Step 7: Optimize the weight map using the guided filter.

$$W_n^M = G_{r_1,\varepsilon_1}(O_n, I_n) \tag{6}$$

$$W_n^N = G_{r_2,\varepsilon_2}(O_n, I_n) \tag{7}$$

$r_1, r_2, \varepsilon_1, \varepsilon_2$ parameters of guided filter

Step 8: By using the weighted averaging method fuse the different source images of base layer and detail layer.

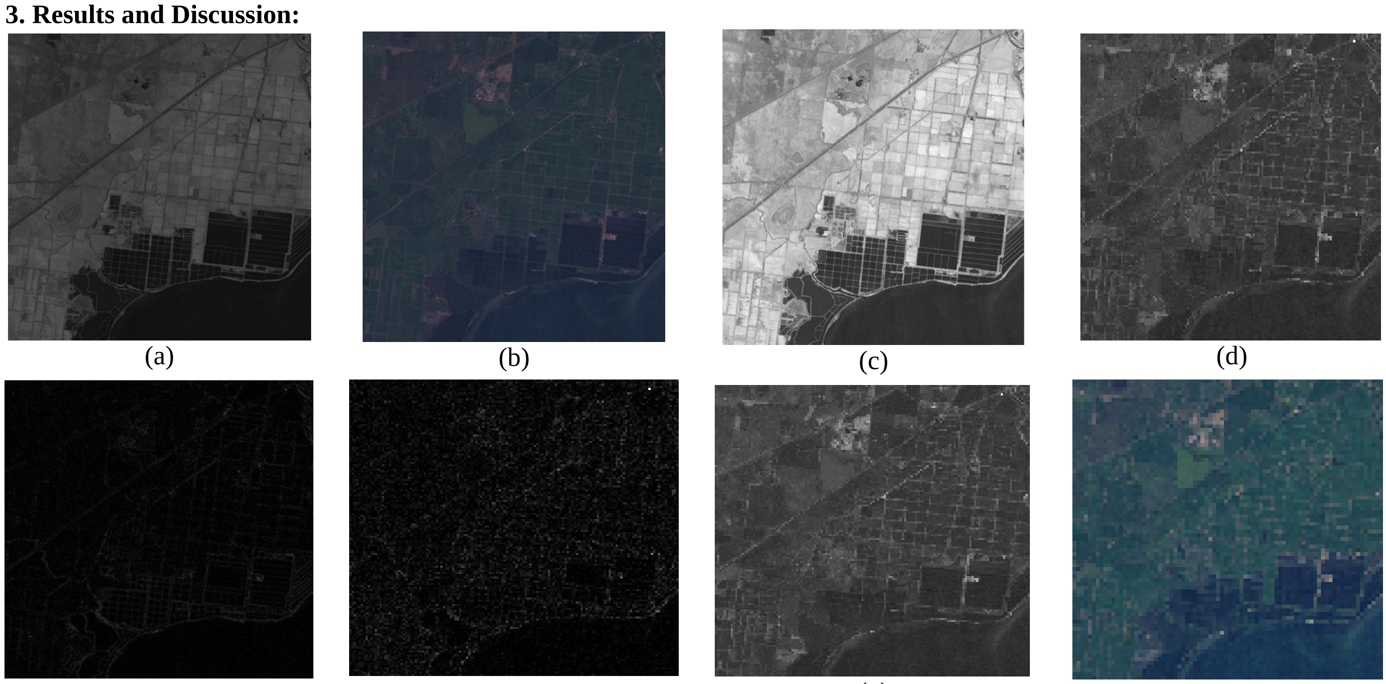
$$\bar{B} = \sum_{n=1}^{N} W_n^B M_n \tag{8}$$

$$\bar{D} = \sum_{n=1}^{N} W_n^D N_n \tag{9}$$

Step 9: Finally the fused image R is obtained by fusing the results of Step 8.

$$R = \bar{B} + \bar{D} \tag{10}$$

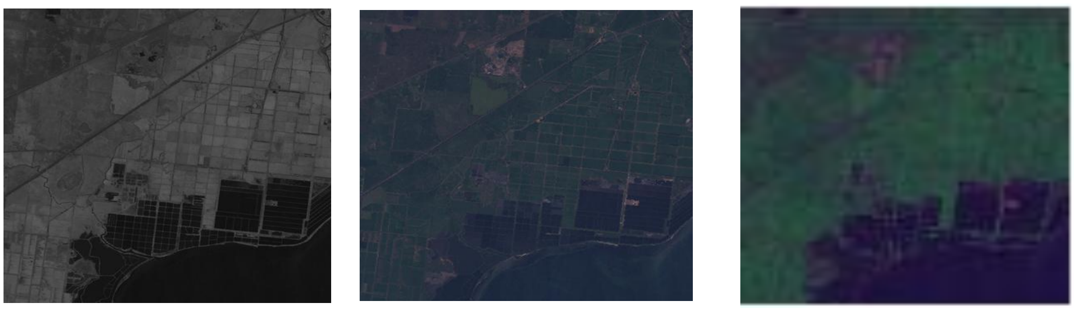
3. Results and Discussion:



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

(e) (f) (g) (i)

Figure1. Result of existing Hybrid Fusion method



a. PAN Image b. MS Image c. Fused image using Guided filter

Figure 2: Result of Fusion method with Guided Filter

Table 1: Comparative analysis of image fusion methods

Parameter	AIHS	HYBDF	FGF
PSNR	71.4821	75.4753	89.4901
MSE	0.0048	0.0046	0.0045
Q_{avg}	0.903	0.9332	0.9870
API	19.2132	21.232	51.3232
SD	4.3230	5.9950	8.1871
AG	0.2321	0.0264	4.0161
D_{λ}	0.0842	0.0821	0.0801

To validate the result of our fusion method with Guided filter (FGF) we considered two component substitution methods like Adaptive Intensity-Hue-Saturation (AIHS) [6], Hybrid Fusion method (HYBDF) [7].

In figure (1), figure (a) and (b) shows the PAN and MS input satellite images used in this paper, figure (c) is the synthetic intensity component image, figure(d) is the MS image in band 1, figure(e) is the Laplacian filterd output which is used to generate the primary and secondary high frequency components, figure(f) is the secondary high frequency component image, figure(g) shows the result of image fusion using existing hybrid fusion method in Band 1, similarly the fusion process is carried out in Band2, Band3 and Band 4, using existing hybrid fusion method. (Only Band1 fusion process result is shown in this paper). Figure (2) shows the fusion method with Guided filter.

From figure (1) and (2) one can clearly observe that the result of image fusion method using Guided filter gives spatial sharpness while maintaining color same as original multispectral image. Table1 gives the performance measurement values used in the fusion process to validate the result. The indexes Q_{avg} , D_{λ} , Standard Deviation (SD) are used to estimate the spectral quality of the fused result. The Average Gradient (AG), Peak Signal to Noise Ratio (PSNR), Mean Square Error (MSE), Average Pixel Intensity (API) are used to estimate the spatial quality of the fused image. Higher the values of PSNR, Qavg, API, SD and AG better the spatial quality and spectral quality. Lower the values of MSE, D_{λ} better the spatial and spectral quality of the image. From table1 we can say that the hybrid fusion method with guided filter gives good results compared to other component substitution methods like Adaptive Intensity-Hue-Saturation (AIHS) and Hybrid Fusion Method (HYBDF) method [8], [9],[10], [11].

4. Conclusion:

In this paper proposed fusion method is compared the two existing methods of image fusion based on component substitution like AIHS, HYBDF. Fusion method with guided filter performs better compared to other two methods in terms of improving the spatial characteristics of the image as well as maintaining spectral quality. Future work can improve the fusion result more accurate by adopting the image registration before image fusion.

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