A Novel Hybrid Pansharpening Method Using Contourlet Transform

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Abstract. In this paper hybrid multispectral image fusion method using contourlet transform is proposed which provides novel tradeoff solution to preserve both spectral and spatial information simultaneously in resultant fused image. Standard Pan-sharpening methods do not allow control of the spatial and spectral quality of the fused image. The color distortion is also most significant problem in standard pan-sharpening methods. Proposed method is applied on number of priori geometrically registered Panchromatic and Multispectral images and simulation results are compared with standard image fusion parameters. The proposed method simulation results also compared six different standard and recently proposed Pan sharpening methods. It has been observed that simulation results of our proposed algorithm is consistent and preserves more detailed spatial and spectral information and better visual quality compared to earlier reported methods.

1 Introduction

In recent years image fusion algorithms are used as effective tools in medical, remote sensing, industrial automation, surveillance, and defense applications. According to Piella [1], fusion process is nothing but a combination of salient information in order to synthesize an image with more information than individual image and synthesized image is more suitable for visual perception. In this paper, we focus on multispectral image fusion application which is an important research area in the field of remote sensing. The synthesis of multispectral (MS) images to the higher spatial resolution of the Panchromatic (Pan) image is called as Pan sharpening method. Various pan sharpening methods have been reported earlier [1][2][3][4][5]; the comprehensive review of most published image fusion techniques described by Pohl and Van Genderen [2]. The natural images contain many intrinsic geometrical structures. In such images, if we apply wavelet transform in 2D than it isolates edges in the images with discontinuities at edge points and smoothness of the boundaries of object will loss. To overcome these limitations, in this paper a novel hybrid multispectral image fusion algorithm based on contourlet transform is proposed. The proposed method is combination of new modified IHS method and Contourlet transform.

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2 Proposed Method

The proposed method is a novel framework which provides novel tradeoff solution to get better spectral and spatial quality Pan sharpened image. The block diagram of proposed method is shown in Fig. 1(a) & (b). Both MS and Pan image are considered as input source image. The IHS color space is used to apply proposed algorithm because of it has less computational complexity and more practical applications. In the proposed method, to increase spectral component while preserving spatial details both input intensity images are considered as source images. The block diagram to generate modified intensity image I_new is shown in Fig. 1. In the block diagram Histogram Equalization (HE), average (avg) and match measure operations are performed. The block diagram of proposed method is shown in Fig. 2. In proposed method both pixel based and region based hybrid image fusion rule is used so this method is called as hybrid method in this paper. It is applied to preserve more details in final Pan sharped image and also it carries advantages of both types of fusion methods. The Pan-sharped image can be generated by following steps as described below.

Step 1. The contourlet transform (CT) [11] applied to the I_new and Im images which decomposes approximation and detail components from each source images which are represented as $I_{ACT,j}$ and $I_{DCT,j}$ respectively. Where j represents decomposion level of CT.

Step 2. Hybrid fusion rule is divided into three categories; pixel based, block processing based and region based. The hybrid fusion rule is applied on CT based decomposed detail image $I_{nDCT,j}$ and $I_{mDCT,j}$ of both source image I_new and Im respectively. The four fusion rules are designed based on four important features parameters contrast, energy, standard deviation and average gradient as explained in [15]. Among these four fusion rules one fusion rule is pixel and region based each and other two fusion rules are block processing based. All the four fusion rules are applied on $I_{nDCT,j}$ and $I_{mDCT,j}$.

The fusion rule 2 and 3 are energy and standard deviation feature extraction parameter based respectively. One region based image fusion rule 4 with average

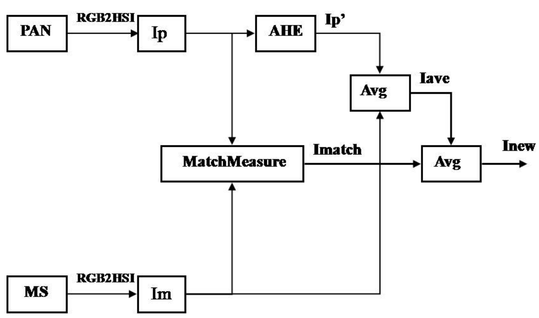

Fig. 1. Block Diagram of Proposed Modified IHS method

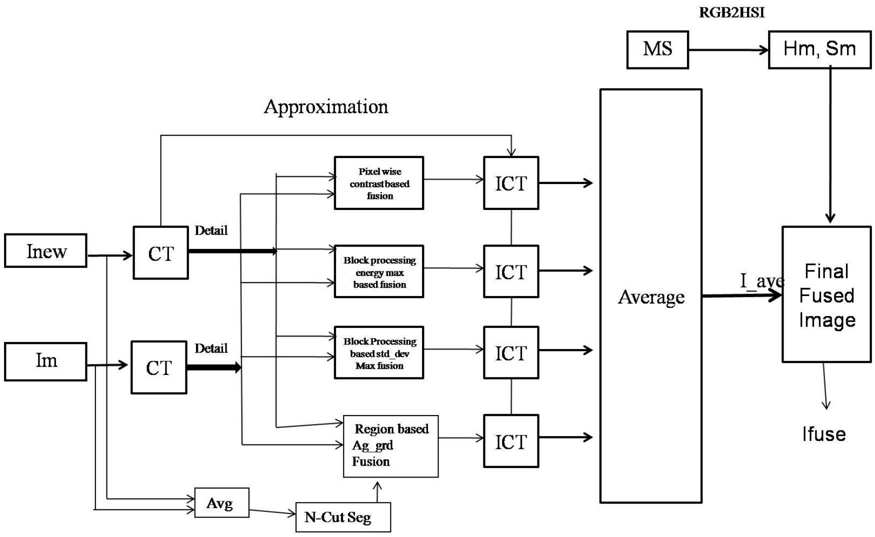

Fig. 2. Block Diagram of Proposed method

gradient parameter is applied. All four fusion rules are described in (1)(2)(3)(4). Fusion rule 1 is pixel based fusion rule based on contrast parameter. The contrast gives information about differences of objects in the image and in this contrast max fusion rule high directive contrast coefficients are preserved in final fused image. First fusion rule is based on contrast parameter first which is defined as

$$I^d_{FC,j} = \begin{cases} I^d_{DCT,j} & \text{if } C^d_{n,j} \geq C^d_{m,j} \\ I^d_{DCT,j} & \text{if } C^d_{n,j,k} < C^d_{m,j} \end{cases} \tag{1}$$

The fusion rule 2 is block processing based energy max rule for window size (M x N). It can also call as directive energy fusion rules. The block of pixels whose directive energy is maximum are saved to be the pixels of the fused image.

$$I^d_{FE,j} = \begin{cases} I^d_{nDCT,j} & \text{if } E^d_{n,j} \geq E^d_{m,j} \\ I^d_{mDCT,j} & \text{if } E^d_{n,j} < E^d_{m,j} \end{cases} \tag{2}$$

The directive SD based image fusion rule 3 is defined as

$$I^d_{FS,j} = \begin{cases} I^d_{nDCT,j} & \text{if } S^d_{n,j} \geq S^d_{m,j} \\ I^d_{mDCT,j} & \text{if } S^d_{n,j} < S^d_{m,j} \end{cases} \tag{3}$$

The fusion rule 4 is region based image fusion rule based on average gradient which is used to compare spatial resolution or clarity of information from the images or regions. The average mean gradient is computed as described in equation (5). The fusion rule 4 is defined as

$$I^d_{g,i,j} = \begin{cases} Rn_i & \text{if } G^d_{n,i,j} \geq G^d_{m,i,j} \\ Rm_i & \text{if } G^d_{n,i,j} < G^d_{m,i,j} \end{cases} \quad (4)$$

Here i is a number of regions and it varies from 1 to n. where $i = 1, 2, ..., n$. Normalized cut set segmentation algorithm is applied on I_new. Segmented regions extracted from image I_new and Im are represented as Rn_i and Rm_i respectively which is extracted using segmentation results of I_new. After applying fusion rule 4 to all n regions; merge all the regions to generate resultant fused image $I^d_{g,i,j}$.

Step 3. Repeat first two steps for all the CT decomposed detail images.

Step 4. Four detail images produced after applying four fusion rules and for all the four type of detail image; $I^d_{nACT,j}$ is considered as common approximation image to apply inverse CT as shown in Fig. 2(a).

Step 5. After applying inverse CT resultant four fused images are averaged to produce final fused intensity image called as $I^d_{F,j}$.

Step 6. Finally, the H and S components of MS image is combined with the $I^d_{F,j}$ intensity image to obtain the final fused RGB image.

All four important activity level measurement feature parameters are considered to compare the details from both source images. Hybrid fusion rule is proposed in the paper to take an advantage of both pixel based and region based image fusion rules. The next section describes evaluation criteria to compare results of different Pan sharpening methods in brief.

3 Simulation Results and Assessment

The test dataset images are downloaded from [9]. The IKONOS-2 images covering an area of the city of Sherbrooke, QC, Canada, also considered as input source images as shown in Fig. 3 (a) and (b) are Pan and MS images respectively [4]. The proposed algorithm has been implemented using Matlab 7. The raw multispectral image taken from the site has been resampled to the same size of the panchromatic image in order to perform registration. Our experiment results show that CT decomposition level 3 provides better visual quality.

Nine segmentation regions are considered to apply region based image fusion rule 4. This value is considered after analyzing different results of different segmentation levels. The most widely used three standard Pan sharpening methods IHS method [2], Brovey Method [7], PCA based method [12] in remote sensing area described in [2] and two recently proposed multiresolution based wavelet transform (WT) [8] and CT based [9] substitution methods are used to compare proposed method.

Average value of each quality assessment parameters of all three band R,G and B of source images are depicted in Table 1. for six comparison methods. All the spectral based fusion parameters are better for proposed method. Spatial quality parameters are better for PCA based method. The average correlation

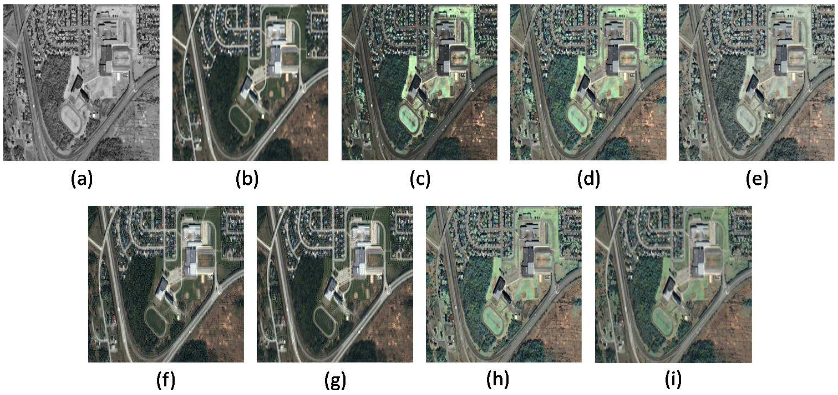

Fig. 3. Fusion Results of IKONOS2 image (a) 1m Panchromatic image (b) 4m Multispectral image(c) IHS Method (d) Modified IHS Method (e) PCA method (f) WT method (g) CT Method (h) Brovey Transform Method (i) Proposed Method

Table 1. Image Fusion Quality Assessment Parameters for Comp Images

Comp	Spectral				Spatial			Common				
	SNR	CC	DE	SAM	SNR	CC	DE	Avg.CC	AG	SD	RCE	MCE
I.H.S. [2]	52.807	0.297	40.196	0.547	56.668	0.926	33.204	0.611	56.374	45.783	0.137	0.102
MI-I.H.S.[7]	52.693	0.353	45.012	0.475	60.932	0.973	11.183	0.663	53.403	43.129	0.128	0.101
PCA [12]	53.716	0.358	48.907	0.460	65.319	0.990	5.359	0.674	61.143	42.999	0.189	0.175
Sub. WT [8]	56.735	0.889	15.355	0.218	54.911	0.519	45.026	0.704	59.357	47.545	0.200	0.197
CT [9]	57.624	0.928	11.986	0.177	54.710	0.452	47.037	0.690	52.335	47.890	0.219	0.202
Brovey [2]	53.151	0.447	41.343	0.434	60.876	0.964	9.695	0.705	50.289	39.822	0.147	0.113
Proposed	**56.028**	0.836	19.629	0.001	55.589	0.693	40.167	**0.765**	51.295	44.584	0.237	0.195

coefficient and average SNR are significantly better for proposed method which shows that proposed method preserves both spatial and spectral parameters better than other reported methods. Proposed method provides novel tradeoff solution. Multiresolution based WT and CT based methods have less color distortion but spatial resolution is affected. The color distortion also very less in proposed method while color distortion is highest in IHS and PCA based method. Resultant Pan sharped image of all seven method are shown in Fig. 3 (c) to (i).

4 Conclusion

There are number of applications in remote sensing that require images with both spatial resolution with less color distortion. The fusion of multispectral and panchromatic images provides a solution by combining the clear geometric features of the panchromatic image and color information of the multispectral image. The proposed algorithm is novel method which uses contourlet transform and hybrid fusion rule framework. Due to this framework, the visual quality and fusion quality assessment parameters of resultant image are significantly better than earlier reported method. The SNR and average CC are remarkably higher than other compared standard and recent methods. The algorithm can be extended by applying artificial intelligent method for more robust fusion. The computational time is only limitation of the algorithm.

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