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Transform based Method for Multi-spectral and Monochrome Images Fusion Using High Pass Modulation Coefficients Technique

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ABSTRACT:

At ideal algorithms for the image fusion Methods, spatial data of monochrome image is added to the multi-spectral image without degradation of spectral information. Frequency-time conversion, such as wavelet and Contourlet the most commonly used algorithms are used in the integration of images and can take images in the frequency domain analysis as well. In this paper, in order to provide a new method, theses transforms, has been used in the images fusion. Our method has been compared with previous techniques such as IHS, PCA, Wavelet and Contourlet transforms. Reported results show that our algorithm has lots of superiority our other methods.

KEYWORDS: image fusion, wavelet, Contourlet transforms, multispectral images, monochrome images.

INTRODUCTION

Nowadays, the application of satellite technology is growing and the diversity of Earth observing satellites are increased. These satellites are utilized for collecting image data by the sensors from earth. The sensors has lots of features and applications for instance, spatial resolutions, spectral and radiometric. Therefore, the urgent need for developing methods and algorithms, should utilize at integration of information from different applications. Possibility of obtaining images with high spatial and spectral accuracies, which may not be feasible due to practical limitations. fusion of satellite images is one of the ways that images can be used to supplement information. Thus, the spatial information from images with high spatial resolution and spectral information from high-resolution images are combined for high spatial and spectral resolution images. Depending on different applications and types of land [1], various algorithms have been proposed to image fusion that such algorithms can be used to overtake it, IHS, PCA [3-4], wavelet and Contourlet. Algorithms Bravi is one of the most basic methods used in images fusion, but the addition of spatial data in these techniques is caused to the spectral information destruction [2]. The proposed algorithms IHS, PCA integrate spatial data into images that are well preserved but the spectral information in these methods is not well maintained and this leads to a color cast in images. One of the traditional but effective algorithms is high pass modulation algorithm in this method; Monochrome image with a coefficient of frequency information is inserted into high-frequency multi-spectral images. This algorithm extracts the high frequency by using boxcar filters [2]. These filters are not conducive to good results in the frequency domain because it contains many ripples in frequency domain. This method has been presented by using mathematical modeling of satellite sensors [2]. With Wavelet transform, the image fusion dramatically improved and the results were much closer to the ideal of fusion. Wavelets that are used for fusion are the two categories. 1 – Reduced dimension wavelets [5] 2-non-reduced dimension wavelet [6]. Results have shown that utilizing reduces dimension wavelet (like Malate), are not suitable for fusion because they lead to the creation of artificial edges [7]. But wavelet without reduction (as wavelet Atrous) one of the most discussed are methods of image fusion. Contourlet Transform is progressive form of Wavelet transformations which in this transform, images, in addition to the frequency domain are separated. Like wavelet, the image fusion using Contourlet, Contourlet without reduction or NSCT [8]. Since the high pass modulation algorithm is obtained using a mathematical model so it seems to be an efficient algorithm, In this paper we improve this algorithm instead of using boxcar filters, here we use the wavelet and Contourlet to extract high frequencies of a monochrome image .

In NSCT, high frequency information of monochrome image is injected to multi-spectral image [8] by directional transform. Thus, the monochrome and multi spectral images and are analysis by NSCT.

Then high frequency information are replaced by specific direction of multi-spectral image. Then inverse converted image NSCT transforms leads to image fusion [9]. The main problem with this approach is that the spatial information of monochrome image is inserted in each band of multi spectral image bands which is wrong a, because each band spatial information are different. For example, images that can be seen in the visible band, the IR band is

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not seen and vice versa. Therefore Satellite multi spectral images with different bands, doesn't have equal spatial information on each bands. So high pass modulation is utilized.

In this paper, monochrome and multi spectral are analysis by NSCT. The high frequency data with specific direction with a modulation index are replaced to high frequency information and the specific direction of multi-spectral image. This procedure is repeated for all directions .Then inverse convert of NSCT, gives us the fusion image.

In the second part, the high pass modulation algorithm is described. In the third section, the proposed algorithm will be presented. Evaluation results are given in part IV and Section V is devoted for conclusion.

2 - the high pass modulation

High pass modulation method main goal is transferring high frequency of image data, with a coefficient to higher frequency of another image. This coefficient relates to LRPI and LRMI. These two parameters are extracted using by using a high pass filter. The mathmatical model is followed in equation 1and 2:

$$DN_{MS}^{h} = DN_{MS}^{l} + (DN_{PAN}^{h} - DN_{PAN}^{l})\frac{DN_{MS}^{l}}{DN_{PAN}^{l}} \quad (1)$$

$$DN_{PAN}^{l} = DN_{PAN}^{h} * \mathrm{h}_0 \quad (2)$$

h_0 is the same as filter which has been used in HPF. The main property of this method is that spatial and high frequency of image is added with factor of DN_{MS}^{l} to higher frequencies of image [12].

In high pass modulation, high-frequency information of monochrome image is injected to multi-spectral images with a modulation coefficient [2]. Coefficients are equal to the ratio of multi-spectral images into a monochrome image. Fusion equation comes as follows:

$$MS_h = MS_l + (PAN_h - PAN_l)\frac{MS_l}{PAN_l} \quad (3)$$

MS_h and MS_l are the multi spectral image and fusion one respectively. PAN_h is the monochrome image, it can be calculated by equation 2:

$$PAN_l = PAN_h * h_0 \quad (4)$$

h_0 is boxcar filter [2]. As is clear, from $(PAN_h - PAN_l)$ high frequency information of monochrome image can be extracted. Unfortunately boxcar filters for high frequency data are not very good and have lots of ripples in the frequency domain. In this article we have tried to extract the high frequency of monochrome images by using the wavelet and Contourlet transforms. Filters used in wavelet have fewer ripples in the frequency domain. In next part modification of high pass modulation method using wavelet and Contourlet is expressed.

3- proposed algorithm

The proposed algorithm can be presented in two different transforms such as Contourlet and wavelet transforms.

3-1 - the proposed method using wavelet

As was stated, wavelets are able to analyze image into different individual frequency bands as well. wavelets (Atrous) that are used to image fusion, use $B_3 - Cubic$ Spline Scale Function [6]. So the proposed high pass modulation algorithm using Atrous wavelet is as follows:

$$MS_h = MS_l + (PAN_h - PAN_l)\frac{MS_l}{PAN_l} \quad (5)$$

In the above equation, $(PAN_h - PAN_l)$ is obtained from the following equation:

$$PAN_l = PAN_h * h_0 \quad (6)$$

h_0 is scale function of $B_3 - Cubic$ Spline . The modified algorithm is used wavelet Atrous instead of the boxcar filter, in order to extract information from high frequency of monochrome. Ripple in the frequency domain and the problem has been eliminated in this way.

3-2 - the proposed method using contourlet

In Contourlet or NSCT, high frequency information of monochrome image is injected to multi-spectral image [8] by directional transform. Thus, the monochrome and multi spectral images and are analysis by NSCT.

(Image analysis using Contourlet is shown in Figure 1). Then high frequency information are replaced by specific direction of multi-spectral image. Then inverse converted image NSCT transforms leads to image fusion [9].

But this method has problems. The main problem with this approach is that the spatial information of monochrome image is inserted in each band of multi spectral image bands which is wrong approach. Because each band spatial information are different. For example, images that can be seen in the visible band, the IR band is not seen and vice versa. Therefore Satellite multi spectral images with different bands, doesn't have equal spatial information on each bands. So high pass modulation is utilized. In our proposed algorithm, monochrome and multi spectral are analysised by NSCT. The high frequency data with specific direction with a modulation index ($\frac{MS_l}{PAN_l}$) are replaced to high frequency information and the specific direction of multi-spectral image. This procedure is repeated for all directions .Then inverse convert of NSCT, gives us the fusion image.

4 - RESULTS AND EVALUATION

IKONOS satellite images with multi-spectral images with a spatial accuracy of 4 m and 1 m spatial resolution and monochrome image is used to evaluate the results of this paper. Evaluation is always in two way 1) visual illustrations 2) numerical illustrations [8]. Other approaches has used for comparing our efficient method such as: Bravi, high pass modulation, IHS, PCA, Atrous and NSCT. Results of the implementation are shown in Figure 2. Visual analysis as the first step of integration is used to evaluate the images. It can be seen from Figure (2c), Fusion with Bravi has caused to cloud color of multi spectral image, but spatial information in this approach is appropriate. Form (2c) shows the result of fusion by using high pass modulation. As is shown in this figure, spatial information of monochrom image has not injection well. IHS and PCA method results are displayed in figure (2I) and (2J). all of these techniques retains monochrome image spatial information but multi spectral information of image has been demolished[2]. At Atrous and NSCT methods, the spatial information is not injected properly and this has led the fusion image looks a little blurry (Fig. (2G) and (2H)). Image fusion using the proposed methods for the detection appear to be more appropriate with eye, but choosing the best one by eye is to some extend difficult. Numerical evaluation is used as a complementary method to assess the fusion methods. Various criteria are used to evaluate the numerical method. In this paper, proposed methods are validated by linear correlation [6], mutual information [10] and QNR [11].

4-1 linear correlation

Linear Correlation measures the degree of closeness or similarity between two images. Linear correlation between images and multi spectral images shows, the accuracy of spectral images which has been sharpen. Linear correlation coefficient is defined as [7]-[9]:

$$\mathrm{Corr}(A,B) = \frac{\sum_{n=1}^{N}\sum_{m=1}^{M}(A(n,m)-\bar{A})(B(n,m)-\bar{B})}{\sqrt{\sum_{n=1}^{N}\sum_{m=1}^{M}(A(n,m)-\bar{A})^2\sum_{n=1}^{N}\sum_{m=1}^{M}(B(n,m)-\bar{B})^2}} \qquad (7)$$

Values of Correlation between the combinations sharp bands and the original MS bands of spectral information should be close to combinations of the correlation. The correlation between image bands multi spectral image fusion and the PAN image should be somewhat higher than the original MS image is much more than this amount. The incensement in the value of this correlation and values close to 1 is not suitable, because it shows that spatial information and the PAN is dominant.

This type of correlation, the linear dependence between two variables reveals .As you know the maximum linear dependence between two variables is equal to 1. The linear correlation between two variables A and B can be calculated from the following equation [7]-[9]:

$$Corr(A,B) = \frac{\sum_{j=1}^{n}(A_j - m_A)(B_j - m_B)}{\sqrt{\sum_{j=1}^{n}(A_j - m_A)\sum_{j=1}^{n}(B_j - m_B)}} \qquad (8)$$

n and m represents the number of pixels are averaged values respectively. Using these criteria for evaluation, correlation between the image and merge monochrome image are calculated, and correlation between multi-spectral image fusion and image are calculated. These two Average values can be maintained and used as a criterion for the spectral and spatial information of multi-spectral image and a monochrome.

4-2 mutual information

Another criterion used to evaluate is, based on mutual information [10]. Mutual information reveals any dependence on the between two variables (even the non-linear type of it). Mutual information between two images A and B as follows:

$$MI(A,B) = \sum_{x,y} P_{AB}(x,y)\log\frac{P_{AB}(x,y)}{P_A(x)P_B(y)} \qquad (9)$$

P_A and P_B the statistical distribution of monochrome images and multi-spectral image, and P_{AB} is combined statistical distribution at monochrome image.

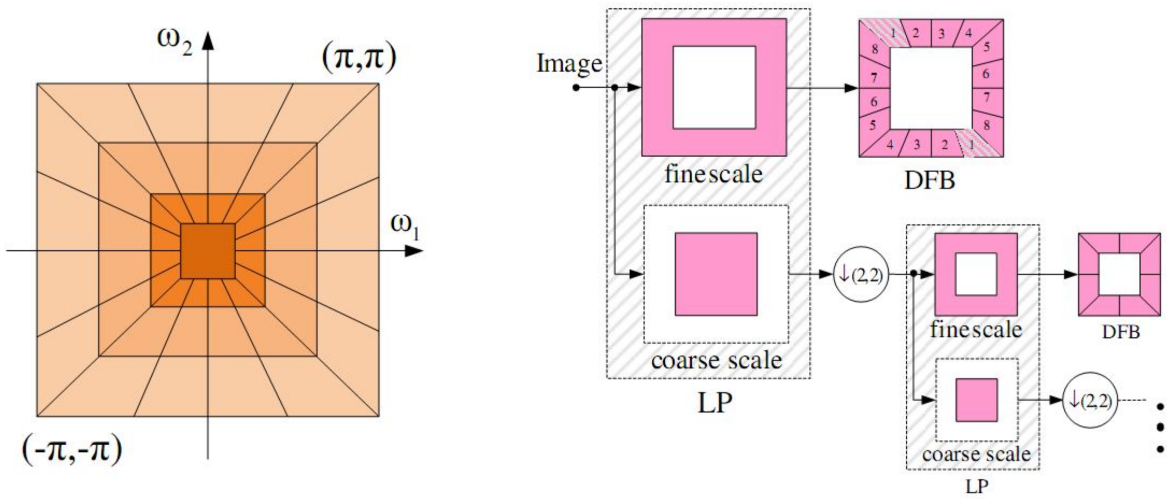

Figure 1 – Image analysis using Contourlet [10].

Figure 2 - (a) multi-spectral image. (B) Monochrome image. (C) Bravi approach. (D) proposed method using Atrous. (E) the proposed method using the NSCT. (F) high pass modulation technique. (G) Atrous Method. (H) Fusion using NSCT. (I) the method of PCA, (J), the IHS.

For evaluation using these criteria, the mutual information between a single primary color image integration and image are calculated and then we calculated mutual information between monochrome image and multi-spectral image. Average mutual information of these two values is as criteria in evaluating the images [10]-[11].

4-3 qnr criteria

QNR is another new criterion can help to assess the fusion image [12]-[17]. This criterion is able to model spectral and spatial distortion. And the fusion image containing all information of the monochrome and multi-spectral image, this value will be equal to 1 (best value for this quantity is equal to 1). Table 1 shows the numerical evaluation of Methods in Figure (2). This table shows that the best result is achieved when integration with high pass modification modulation algorithm with NSCT is proposed.

TABLE 1 SHOWS THE NUMERICAL EVALUATION OF METHODS IN FIGURE (2)

Methods	IHS	PCA	Bravi	NSCT	Atrous	H. P Modulation	Proposed method by Atrous	Proposed method by NSCT
Linear Correlation	0.82	0.82	0.81	0.91	0.89	0.88	0.95	**0.97**
Mutual Information	0.33	0.33	0.32	0.39	0.36	0.31	0.43	**0.51**
QNR	0.77	0.78	0.75	0.87	0.86	0.81	0.92	**0.94**

5 conclusions

This paper uses the wavelet and Contourlet transforms for fusion of multi-spectral and monochrome image. In our method, the high-frequency information is extracted with wavelet and Contourlet from a monochrome image, and then this high frequency information is injected to multi-spectral image by the coefficient of frequency modulation. The modulation coefficient obtained from the image sensor which has been obtained from mathematical modeling. In doing so, the high pass modulation methods have improved so that instead of using the boxcar filter and wavelet.

Besides that, obtained images were visually evaluated. Although visual assessment is not accurate, but distortion of images was evident in some of the methods. Then the obtained images were evaluated numerically. Numerical evaluation verifies visual assessment results.

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