Enhancing the Quality of Satellite Images Enhancing through Combination of Feature and Pixel Level Image Fusion

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ABSTRACT:
Up to now, several methods have been proposed for image fusion in pixel level and feature level for quality enhancement of satellite images. From these methods, methods based on discrete wavelet transform (DWT); intensity hue saturation (IHS); and high pass filtering have attracted much attention. But in methods based on; intensity hue saturation and discrete wavelet transform each have disadvantages such as chromatic aberration and linear discontinuity of location characteristics. The present article proposed a new and effective method for fusion in pixel and feature level and by combining the mentioned methods intelligently; the new proposed method maintains the significant and salient characteristics of input images and simultaneously overcomes the mentioned weaknesses. Results are product of experiments evidencing this claim.

KEYWORDS: Image Fusion; Quality Enhancement of Images; Multi-Spectrum Images; Discrete Wavelet Transform; High Pass Filtering.

1. INTRODUCTION

Image fusion is a process in which two or more images of a scene are combined and produce a new image, in a way that the produced image is more appropriate than initial images for objectives such as visual perception and computer processing [1]. Image fusion causes the results obtained in output to be more reliable and utilizable in different usages. There are three different levels in Image fusion nalmely: 1) pixel level fusion: 2) feature level image fusion 3) decision level image fusion [7]. In fusion in pixel level which is considered in the lowest process level, raw pixel images of a scene from different measures are combined to create a new image. In fusion in feature level, referred to as midlevel fusion, some features from the main images are derived and combined in a general feature vector. This fusion requires extraction of best known objects and features in different sources by segmentation process and also feature extraction algorithm. Normal features such as edges, lines, corners and… are extracted from different images and fused in different ways. In decision level image fusion, known as high level fusion, a method is presented which exploits additional information. This information is added to the characteristics derived from source images and the obtained information is used for better understanding of concepts and information by decision making rules and ultimately the final decision is made.

There is an important part in fusion algorithms in all level called fusion rule. In fact, in pixel, feature or decision level, when important information is obtained from all images, there should be a rule to select the more efficient data. The rule is named fusion rule. Selecting the maximum of coefficients, or averaging in coefficients are the most common fusion rule [2].

In recent years, several methods are presented for fusion in pixel level. The easiest method is getting average from input images as pixel to pixel. This is an applied method but undesirable effects such as lowering brightness and mosaic effects in the fused image are observed. If images are multispectral (In this article PAN and MS images are used), fusion methods based on DWT and IHS will be utilized more. In recent years, using multi-resolution transforms such as discrete wavelet transform has been welcomed very much. Several other methods such as high pass filtering of HPF pyramids are suggested. Wavelet transform is a mathematical tool for hierarchical analysis function. After manifesting their efficiency in processing signals, they have been received very much in image process and especially in image fusion. Wavelet transform may be considered an effective localization in the field of location and frequency. Compare to other multi-resolution transformations, wavelet transforms are more compressed and may generate information in three directions (vertical, horizontal and diagonal) and also approximation [4]. In recent decades, using wavelet transform for image fusion has been increased every day [6] Methods based on IHS are one of the most popular methods used in merging MS multispectral images with PAN color images. No matter what model is selected for spatial transformation of RGB to HIS, the principle and rule for HIS transform is image fusion according to human system perception of color. In this transformation, spectral information of RGB is placed in two parts of H and S, while most location information will be in I component. Image fusion based on HIS transform has been welcomed because of simple algorithm, comprehensibility and rapid calculation [8] and [11].

The paper is organized as follow, in section 3 the basic of discrete wavelet transform is explained. also foundation and principles of HIS transform will be explained. In section 4, new proposed method for satellite image fusion based on combining IHS, RWT and DWT methods in feature level and pixel level is presented; finally, section 5 will evaluated proposed methods using IHS, RWT and DWT methods separately and in last conclusion will be delivered in section 6.

2. LITERATURE REVIEW

In [7] proposed a new method with the aim of improving fusion methods. This research has been concentrated on fusion methods based on high resolution. In these type of methods an image with limited spectrum and high resolution is fused with data of images with low resolution and more expanded spectrum in order to gain a multispectral image with high resolution. During this process, all spectral characteristics of multispectral data will be maintained. This research compares eight different fusion methods to study the performance of suggested method and results indicate that. The proposed fusion method by Ehler will improve the algorithm performance in relation to other compared methods.

In [8] has been concentrated on the issue of fusion of images with multiple focuses. This research utilizes several fusion rule such as averaging, analysis of major components, discrete cosine distribution, wavelet discrete transform and neural network to solve these problems and has studied the advantages and disadvantages of each one. Research results indicate that using FPGA (Field Programmable Gate Arrays) will improve the speed and quality of images resulting from fusion. A reason for researchers' attention to the field of image fusion in recent years is the contradiction between spectral and spatial characteristics of images in fusion phase. Establishing equilibrium between these features has been discussed in different researches.

In [19] have proposed a new method for satellite multispectral image fusion through combining techniques for analysis of major components and fuzzy logic. The objective of this research is to establish equilibrium between spectrum and space characteristics in fused images, in a way that one may gain the highest level of information in final images. For this purpose, we first derived characteristics of images through analysis of main components and then the main component was utilized to determine the interval of components' coefficients changes. Afterwards, fuzzy logic was used to combine the main component with multispectral images.

In [13] used images system characteristics to improve image fusion results. This algorithm initially used wavelet multilevel analysis to transform images to a collection of coefficients and then combined the information of color image in each spectrum of multispectral image; through wavelet inverse transform on analysis coefficients the final fused image was made. In [11] have proposed an image fusion algorithm based on MGS (Modified Gram-Schmidt) algorithms and discrete wavelet transform. In this method, initially the main image is combined through MGS transform with smaller images and after histogram equalization; wavelet transform was used to transform characteristics of images collection. Finally, by inverse application of wavelet transform and MGS, final fused images were resulted.

In [18] proposed a method to compress images by multiple-resolution. This method which is a compression algorithm with loss uses discrete wavelet transform and is able to compress images with high resolution in a short time frame (interval). The prposed algorithm is able to maintain spectral information and space in resultant images very well.

In [12] has emphasized on diagnosing water level changes in satellite images. This research combines two techniques of image fusion in pixel and image classification levels. In this method, primarily, variable regions are specified by image fusion technique in different time intervals. In order to fusion images, discrete wavelet transform has been utilized and then synthetic neural network and support vector machine is used to classify types of specified changes in fusion phase.

In [1] used entropy criteria to fusion images with RGB color system. The proposed method in this research is a combined model which utilizes major component analysis, discrete wavelet transform and high pass filtering to fusion images. This method applies discrete wavelet transform after changing dimensions of each image and passes them through high pass filtering. Then coefficients resulting from these two phases are combined through fusion rule based on analyzing major components and finally fused final image is produced and evaluated according to entropy criterion.

In [3] proposed a method to fusion satellite image data based on utilizing diagnose earth surface cover. In this method diagnosis is made in two steps: Initially, a map of earth surface cover is produced using multispectral images data; then in second phase, a classifier is used to provide a sub-collection of classes for primary map. This classifier uses all available information in multispectral images and for this purpose a data fusion algorithm is utilized to separate image regions and their storage in multidimensional space. Classifier fusions information of each layer with the produced map and diagnoses each coating type in the image surface separately.

3. BASIC CONCEPTS

3.1. Discrete Wavelet Transform

Discrete wavelet transform provides a format in which signal is analyzed and each level is proportional to its accuracy. There are two major kinds: a) discrete wavelet [17]. Although explaining and describing continuous wavelet is mathematically easy, both wavelet functions and signals should be alike which makes it implementation nearly impractical. Discrete wavelet transform (DWT) is welcomed more, because discrete is made from a collection of scale transfer and change and also discrete sampling of signal. In order to simplify, it is assumed that sampling is binary but concepts may be generalized to selection of other factors. DWT utilization process may be illustrated as a bank of filters. As is shown in figure 1, in each level of analysis signal is divided to high and low frequencies. Low frequency may be analyzed till the arbitrary accuracy. The main signal may be restructured by utilizing reverse transform to all levels analyzed in the level of resolution. A normal DWT may be implemented by using through using decimated and undecimated algorithms. Furthermore DWT may be implemented by a non-analyzable algorithm, too [9].

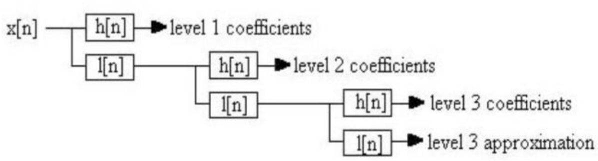

Fig.1. DWT for a one-dimensional signal in three levels.

3.2. Intensity-Saturation-Hue Transform

An image is created by false color through injecting 3 spectrums into monitor by blue, red and green light guns. In this process, different percentages of these main colors ate combined with each other to produce different colors like yellow, violet and …. Figure 2 shows cubic of colored image; these images are called RGB.

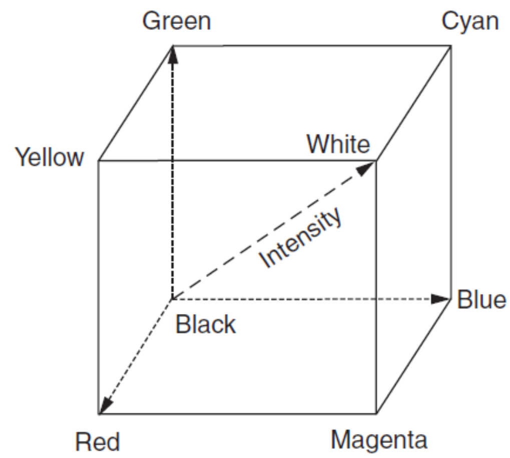

Fig. 2. Cubic model to illustrate RGB.

If the intensity of blue, red and green colors are alike, their combined color may be colorless like grey [12] .In other view a color image may be described by three parameters: 1) Intensity, 2) Saturation, and 3) Hue. H color is the same specific color such as red, green or blue, depending on its wavelength. For instance, blue light has wavelength equal to 0.4-0.5mm. Saturation (S) is defined as color purity or it may be said that it is the proportion of pigment (colorful) to grey value. Intensity (I) is referred to as color brightness. As it may be observed, intensity is proportional to the average of three main colors (R red, B blue, G green).

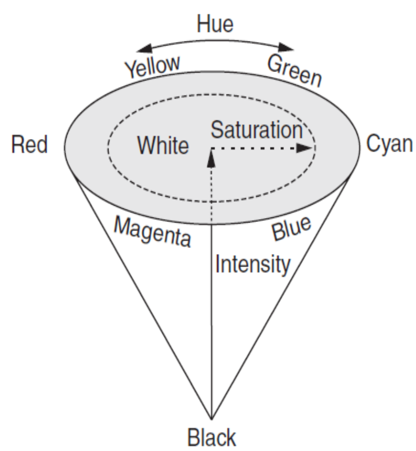

Fig.3. Conical model for illustrating RGB.

Every color image can be described by these three parameters through Commission Eclairage International (CIE) curve. Outer borders of CIE are proportional to hue; saturation is calculated by measuring the distance between corresponding point and outer layer. Intensity (I) which is referred to as value, too, is the distance between cone base from its apex [12]. This transform of pixel values from RGB to HIS requires utilizing new coordinates. In this new system, Hue is considered as the proportion of colorless point rotation degree. Saturation is defined as the vector length of colorless point to R, G, and B points. This is while intensity is the length of main vector. After employing this system, an image in RGB space, is transformed to IHS point by equation 1-3.

$$I = \frac{1}{3}(R + G + B) \tag{1}$$

$$H = \tan^{-1}\left[\frac{R-G}{\sqrt{3}I}\right] \tag{2}$$

$$S = \sqrt{0.5}\sqrt{3I^2 + (R-G)^2} \tag{3}$$

Transformation from RGB space to IHS space provides an accurate imagination from color and its illustration. This useful tool is more practical in order to improve the quality of images in fusion. After fusion is fulfilled, image is converted from IHS to RGB space.

4. PROPOSED METHOD

Image registration in field of image fusion is an important issue. Spectral and special resolution of PAN and MSI are different. The registration process is complicated and there are several of method to register the different images are proposed by researcher. Image sharpening and changing sharpness of edges is one of most important visual features in image. DWT is a suitable mathematical tool for identifying multiscale edges. Transformation of a'trous wavelet without any loss provides the opportunity for image to be analyzed to intermediate channels near the frequency field, without the loss of high frequency details of location connections. Therefore, in proposed fusion images, the intended PAN image is analyzed by DWT, then edge features in I component of MS transformed image will be maintained and extracted level by level. Extraction of edges' detail will be obtained easily by adding their simple kind. Experiment results indicate that total RWT designs from each image indicate the main edge information. Fusion method according to the suggested merging method acts in the following way: at first MS image is transferred from RGB field to IHS field and then input pan image is analyze by altrous algorithm; then details of extracted edges are compared with the details of first band available image in IHS field by fusion image, in other words the fusion rule of proposed method is as following equation (equation 4).

$$\begin{cases} if \quad M \geq EED \\ \qquad F = M \\ else \\ \qquad F = EED \end{cases} \tag{4}$$

The block diagram of proposed method shows in *Figure4*. The result of this comparison is creating fusion image F; where M is the first band in IHS space, and EED is details of improving and enhancing edges. Finally, the image resulted from IHS will be transferred back to RGB space.

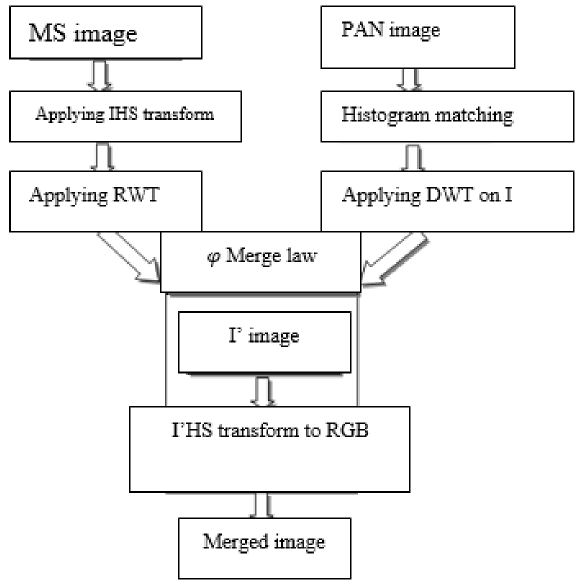

Fig. 4. Diagram block of proposed method based on DWT, RWT and HIS.

5. EXPERIMENTAL RESULTS

In order to demonstrate and evaluating the superiority of the proposed method the in experimental and practical method, the proposed method based on DWT, RWT and IHS that named DR_WT_IHS were implemented on many of MS and PAN images which all were registered before. Also, methods based on DWT, and IHS were separately implemented on the same images to examine effectiveness of the proposed method. Figure 6 shows the original PAN image, and figure 7 shows original MS image from Landsat satellite and figure 8 shows the fused image based on DWT. Figure 9 shows the result of fused images based on HIS transform. Finally figure shows the fused image of new proposed method DR_WT_IHS. There are two types of evaluation and comparison of results namely qualitative comparison and quantitative comparison.

5.1. Qualitative comparison *criteria*

In qualitative comparison fused images are compared visually. As it may be found from results and images, in the method based on HIS and DWT, while the quality of MS image has been enhanced, it hasn't been able to show their priority. Nevertheless the proposed method based on combination of RWT, DWT and IHS that named DR_WT_IHS has effective premium quality, in a way that green spaces and building have been separated very well with more true colors. The quality comartion also done on image chosen from SPOT satellite in which results are observed clearly. In second comparison, evaluation have been done on images based on Evaluation criteria. Chosen from SPOT satellite in which results are observed clearly.

Fig. 6. Original registered PAN Image.

Fig. 7. Original registered MS Image.

Fig. 8. Fused image based on DWT.

Fig. 9. Fused image based on HIS.

Fig. 10. Fused image based on DR_WT_IHS.

5.2. Quantitative Evaluation Criteria

While qualitative comparison suggests the priority of suggested method, in order to assure it, quantitative evaluative criteria are used. There are two types of Quantitative evaluation criteria, first type measures the information of fused images, and the second type evaluate the fused image with original MS image. Average (AVG), entropy (ENT), spatial frequency (SF), cross entropy (C.ENT) and standard deviation (SD) and average gradient (AG) measure the amount of information in fused image and also original MS image. these criteria are in type I. Criteria such as cross correlation (C.C), mean average error (MAE), signal to noise ratio (SNR), pick signal to noise ratio (PSNR) and root mean square error (RMSE) evaluate the fused image and original MS image, and fall in type II. (13) (14) (15) (17) (18). For more evaluation the proposed method Figure 10: Fused image based on DR_WT_IHS was evaluated with method based on DWT, and fusion based on principal component analysis (PCA), Brovy Transform (BT), IHS and high pass filtering (HPF). Table 1 shows the results obtained for three bands in type I. As observed from the results, the new proposed method DR_WT_IHS is significantly better than methods based on PCA and HIS and other method. Of course computational cost increased, but information of fused image satisfying the cost of proposed method. In selective criteria, except for C.ENT, higher numbers indicate enhancement of image quality and increase of information fused in the image (16). As is evident in the table, almost in all cases of the selected image, this increase may be observed. For C.ENT the lower number indicates the premium quality and descending order of the criteria, too, is observed clearly which suggests the supremacy of new proposed method DR_WT_IHS. The lower entropy and cross entropy of image, shows more information in image. And C.ENT and ENT of proposed fused method is the least and proof the fused image is more informative. The higher value of SF, SD, AG shows the better result and proposed image shows its preference With the highest value.

Table 2 shows the result of implementation and evaluating the proposed method and other mentioned methods.

Table 1. Comparing the proposed method with previous works.

Criteria / Method	AVG	ENT	SF	C.ENT	AG	SD
BT	109.4	5.15	37.48	0.0089	19.17	3.68
IHS	78.3	0.95	54.59	0.0227	45.38	3.67
HPF	119.8	0.91	51.89	0.0101	17.91	3.41
PCA	138.6	0.89	56.66	0.0010	35.30	3.72
DWT	107.5	0.95	59.75	0.0130	46.38	3.73
DR_WT_IHS	**110.6**	**0.90**	**71.79**	**0.001**	**51.9**	**3.71**

Table 2. results of type II criteria

Criteria / Method	C.C	MAE	SNR	PSNR	RMSE
BT	1.33	26.53	23.48	21.43	41.5
IHS	0.55	61.11	39.84	21.44	34.42
HPF	0.94	24.56	30.27	34.99	24.10
PCA	1.26	33.61	25.29	31.97	40.62
DWT	0.86	25.77	38.20	29.96	25.14
DR_WT_IHS	**1.10**	**24.92**	**47.00**	**30.127**	**26.19**

As table 2 shows, the proposed DR_WT_IHS method shows superior results. In one hand the higher SNR and PSNR shows the better results. The proposed DR_WT_IHS method shows 47.0089 and 30.1275 respectively and proof the Excellency of proposed method. And in other hand lower MAE and RMSE shows the better result and proposed method has the lowest value in table 2. Although the lower C.C value lead to better image, the proposed method does not lowest value, that does not mean the proposed method, work bad. And the result C.C is acceptable.

6. CONCLUSION

A new method for image fusion was proposed based on combination of RWT, DWT, HIS called DR_WT_IHS which omitted the disadvantages of basic methods such as chromatic aberration in HIS and location discontinuity in linear characteristics of method based on DWT, and improved the image apparent quality compared to the mentioned methods. These methods have been implemented on several images of Landsat and Spot satellites. Based on both of qualitative and qualitative criteria, from the evaluations, it was concluded that the suggested new method is more efficient and effective.

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